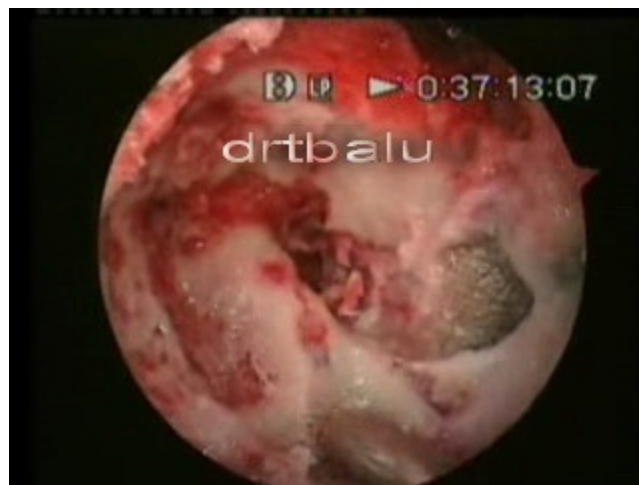


Reconstruction of middle ear cavity

By

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Introduction: Reconstruction of middle ear cavity is a necessity in the surgical management of suppurative lesions of middle ear cavity. It can be performed as a single stage procedure or in multiple stages (staged procedure). The decision of single / staged procedure is made taking into consideration the severity of the disease and the ability of the surgeon to clear the disease.

Aim of middle ear reconstruction surgery:

1. Disease clearance
2. Reconstruction of sound transmission mechanism
3. Skin lined mastoid cavity, which is exteriorized and accessible to cleaning by the surgeon
4. Restore an air containing middle ear space

Before embarking on middle ear reconstructions following steps must be taken:

Meatoplasty (Canalplasty):

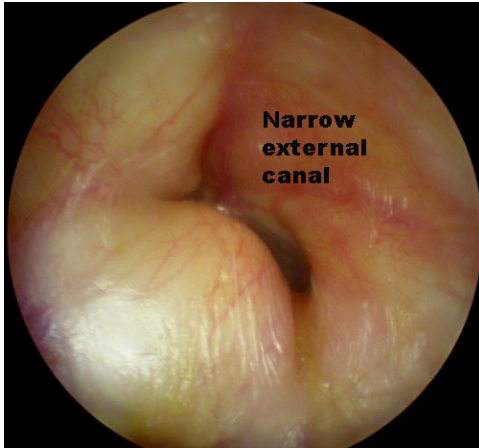
The size of the external auditory canal should be adequate for surgery. If there is narrowing external auditory canal then a canalplasty should be performed. Canalplasty is a surgical procedure performed to widen the cartilaginous / bony portion of the external auditory canal. Adequate cartilage should be removed if the cartilaginous portion is narrow, and external canal bone humps can be removed by drilling if they cause narrowing of the external canal.

Mastoidectomy:

Mastoid air cells are drilled open in this surgical procedure. This is performed to clear the diseased air cells. The mastoid air cells are also exteriorized.

Myringoplasty:

This surgical procedure is performed to close the perforated ear drum. The tympanic membrane is not elevated from its sulcus. This helps not only in improving the patient's hearing, but also protects the middle ear from infections



Tympanoplasty:

This surgical procedure is performed to eradicate disease in the middle ear cavity and to reconstruct the hearing mechanism. The tympanic membrane is usually elevated from its sulcus. This procedure could be performed along with / without mastoid surgery.

Ossiculoplasty:

This procedure is performed to repair / reconstruct the ossicular chain.

History:

- In 1640 Banzer first attempted to repair a perforated ear drum using pig's bladder. He placed the graft laterally.
- In 1853 Toyenbee placed a rubber disk attached by a silver wire over the perforated ear drum and demonstrated improvement in hearing.
- In 1863 Yearsley replaced the rubber disk used by Toyenbee with a cotton ball
- In 1876 Roosa treated ear drum perforation with electrocautery
- In 1877 Blake used a paper patch to close the ear drum perforation
- In 1878 Berthold coined the term Myringoplasty. He placed a cork plaster over the ear drum to peel off the epithelium. He used free thickness skin graft over the perforation to close it.
- In 1921 Nylen introduced a monocular operating microscope.
- 1922 Holmgren teacher of Nylen introduced binocular microscope
- In 1950 Zollner and Wullstein used split thickness skin graft over a de-epithelized ear drum to close the perforation
- In 1956 Wullstein described 5 types of tympanoplasty which is still valid
- In 1957 Shea performed the first underlay grafting of ear drum perforation using vein graft

- In 1961 Storrs first used temporalis fascia as grafting material
- In 1964 Chalat introduced tympanic membrane allografts
- In 1967 House refined the technique of tympanic membrane grafting. He was the first person to insist that the edges of the perforation be trimmed for better graft take-up

Mastoidectomy:

Aims of this surgery include:

- Exenteration of infected mastoid air cells
- Widening the aditus
- Restoration of a air filled middle ear cavity
- Repair of sound conducting mechanism

Types of mastoid surgeries:

1. Open mastoidectomy / Canal wall down mastoidectomy
2. Closed mastoidectomy / Canal wall up mastoidectomy

Open mastoidectomy / Canal wall down mastoidectomy:

Indications:

- Attico antral disease (cholesteatoma)
- Attic block causing persistent ear discharge

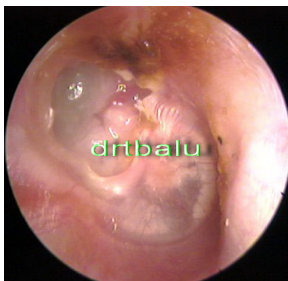


Figure showing attic antral disease



Figure showing attic cholesteatoma

In this surgical procedure the outer attic wall and posterior canal wall is removed. Mastoid air cells are exenterated.

A single cavity comprising of mastoid cavity, aditus, antrum and middle ear cavity is formed. This cavity is exteriorized by performing a wide meatoplasty.

To understand this surgical procedure certain anatomical definitions must be made clear.

The major disadvantage of this procedure is reduction of the middle ear space.

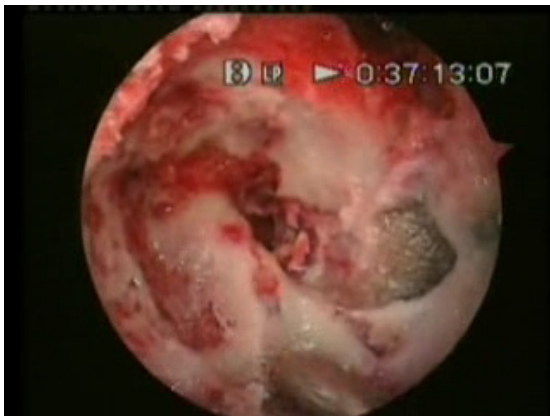


Figure showing open mastoid cavity

Different types of Mastoidectomy procedures have been described in the literature. In this article we are making every effort to clear the air and put to rest the confusion which has been reigning so far.

Several basic terms, such as atticotomy, attico antrostomy, simple Mastoidectomy, conservative radical operation, classic radical operation and tympanomastoidectomy have often been described.

Atticotomy:

Otherwise also known as epitympanotomy, denotes opening of the attic, performed through the transmeatal route. In this procedure the lateral wall of the attic is drilled away and the lateral attic is exposed.

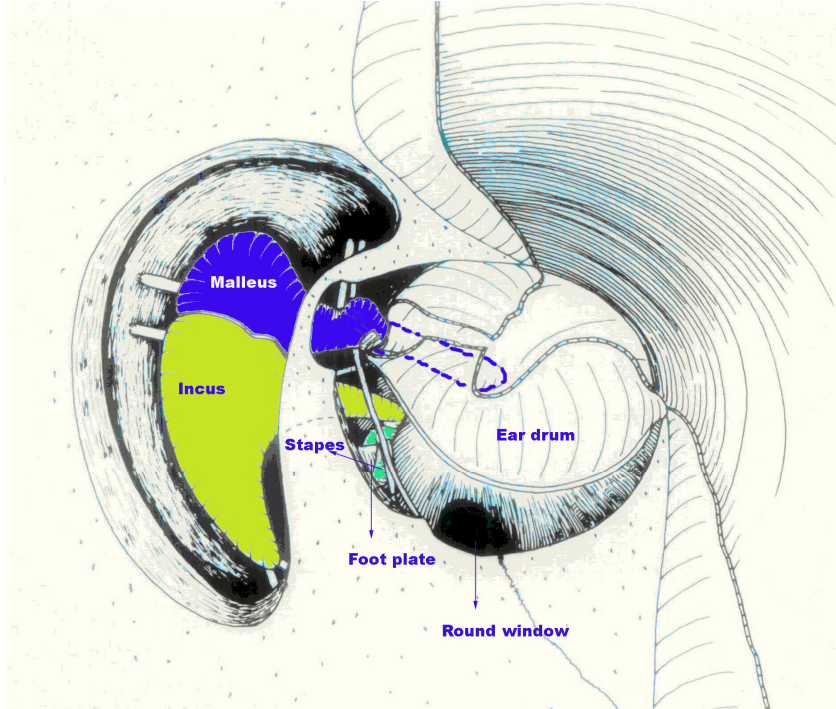


Fig1. Demonstrates Atticotomy with preservation of bony bridge

Atticotomy can be performed in several ways, leading on to various modifications:

1. Preservation of the bony bridge, by drilling superior to the bony annulus and widening it towards the tegmen tympani as indicated in the figure 1.

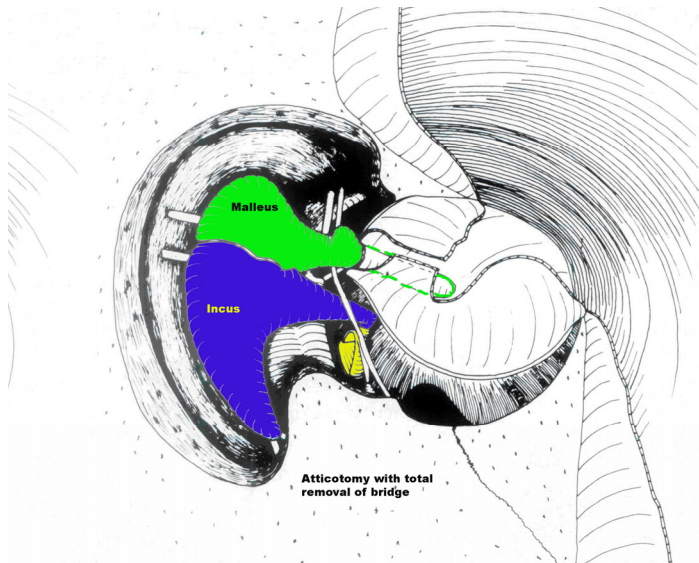


Fig 2 : Atticotomy with total removal of bony bridge

2. Total removal of the bony bridge together with the lateral attic wall up to the level of tegmen tympani, exposing the lateral attic, the ossicles and the ligaments as shown in fig 2. In cases of resorption of the ossicles or removal of the remnants of the ossicles, the atticotomy can be further extended and the medial attic exposed.

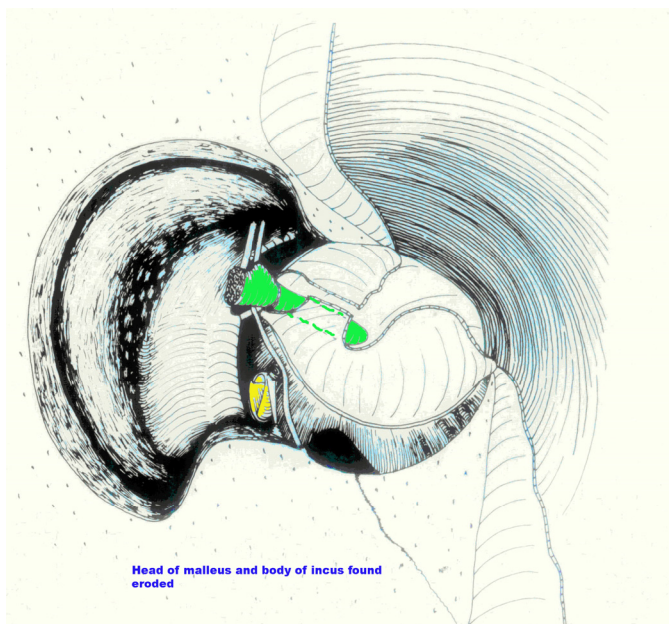


Fig 3 Here the medial attic is exposed because of resorption of malleus head and incus body

3. In cases of resorption of the ossicles or removal of the remnants of the ossicles, the atticotomy can be further extended and the medial attic exposed. (Fig 3).
4. Partial removal of the bony bridge. This situation can be caused by spontaneous resorption of the bony annulus by cholesteatoma; or by drilling in cases in which there are difficulties in removing cholesteatoma at a particular point; or lastly in cases with fixation of malleus. (Fig 4)

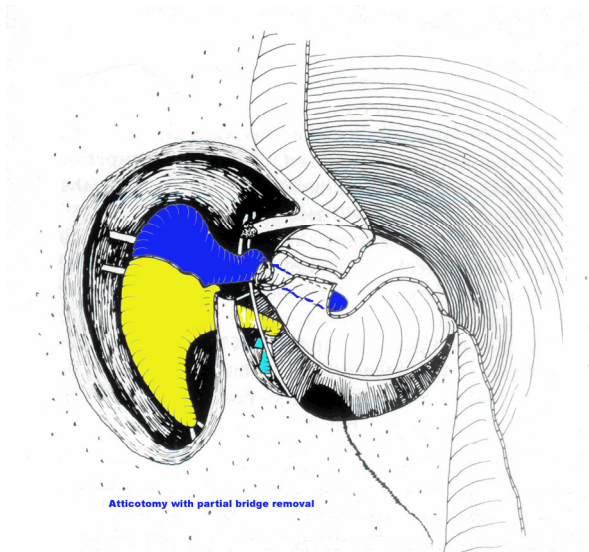
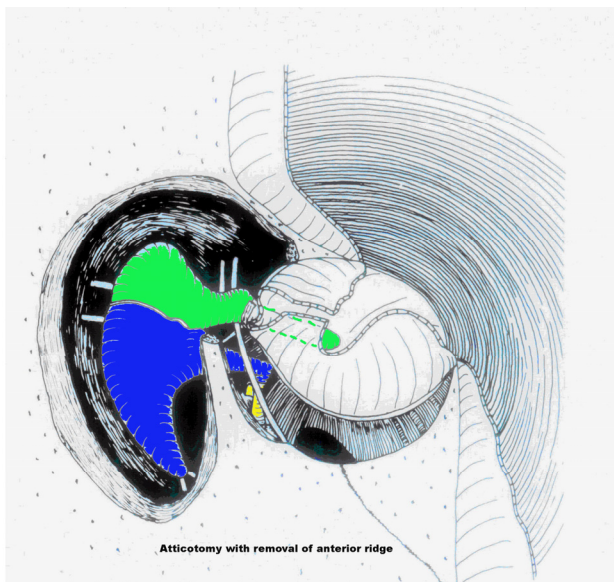


Fig 4 showing atticotomy with a partially removed bony bridge

5. The bridge can be removed or be resorbed in the middle as shown in Fig 4. In the anterior part as shown in fig 5.



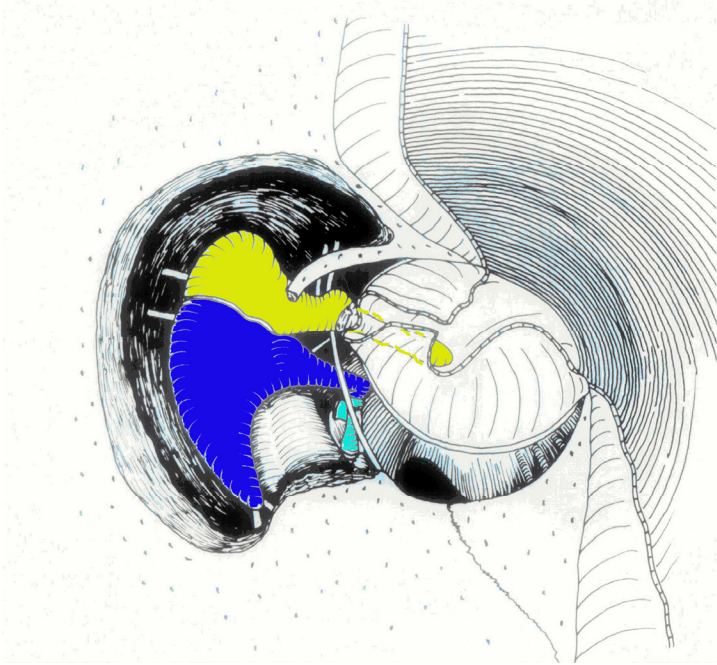


Fig 5. Atticotomy with removal of anterior part of bony ridge.

6. In attic cholesteatoma there is often resorption of the bone in the region of Sharpnells's membrane (the scutum), and the bridge cannot remain intact in its middle or anterior part.
7. In sinus cholesteatoma, starting with a posterosuperior retraction of pars tensa, the posterior part of the bridge can be resorbed, or may have been removed to gain better access to this region. (Fig 6)
8. Displacement of the intact bridge - In cases with attic cholesteatoma and spontaneous resorption of the bridge, or in cases requiring drilling of the bony annulus in order to provide better exposure of the mesotympanum, part of the superior bony annulus (the scutum) is drilled away, displacing it superiorly. After the atticotomy, the new bridge is positioned more superolaterally than the original bridge. This type of displacement of the bridge occurs after performing an

anterior atticotomy in order to remove the tensor tympani fold and the bony plate in the anterior attic to improve the ventilation through it. (Fig 7)

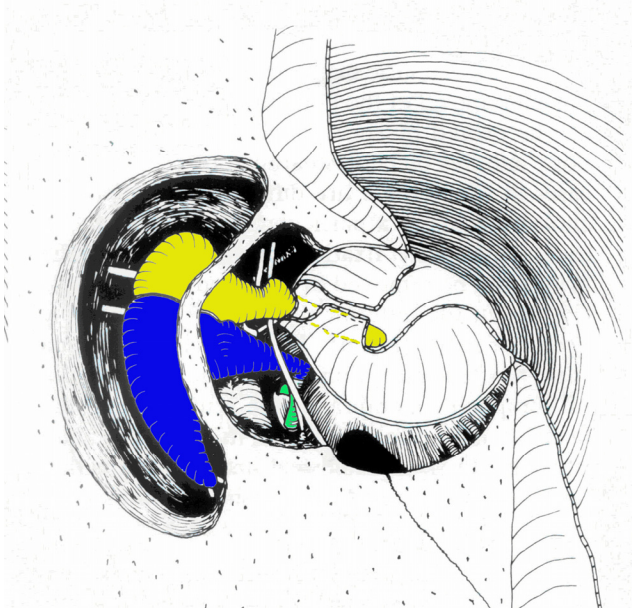


Fig 7 Atticotomy with superolateral displacement of an intact bridge.

Even though methods involving removal of the bridge have been popular it is always better to preserve varying amounts of bridge in order to maintain the middle ear space. Of course sacrificing the bridge saves lot of time during surgery.

Atticoantrostomy:

Is nothing but an extension of the atticotomy in a posterior direction through the transmeatal route. The lateral attic and aditus walls are removed, and the antrum is entered. The posterosuperior bony can wall is removed, and the access to the antrum is gradually widened. (Fig 8 & 9)

In cases with poor pneumatization, a small antrum, and a sclerotic mastoid process, an atticoantrostomy results in a small cavity with smooth walls. (Fig 9)

In a large cell system, the atticoantrostomy results in a large cavity.

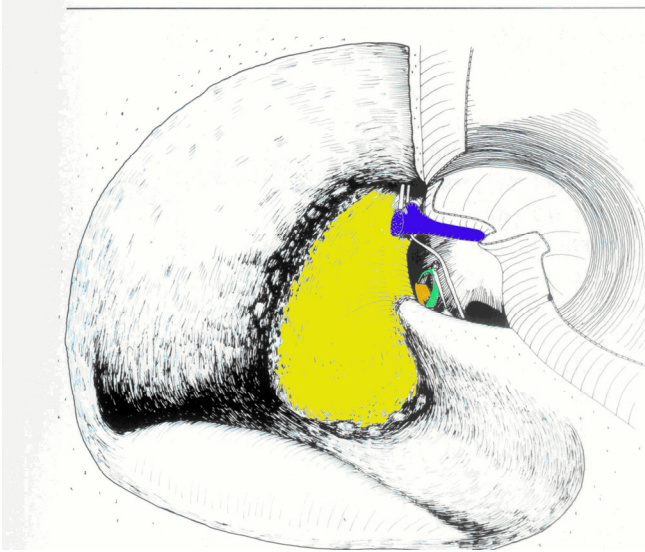


Fig 8 showing a large atticotomy

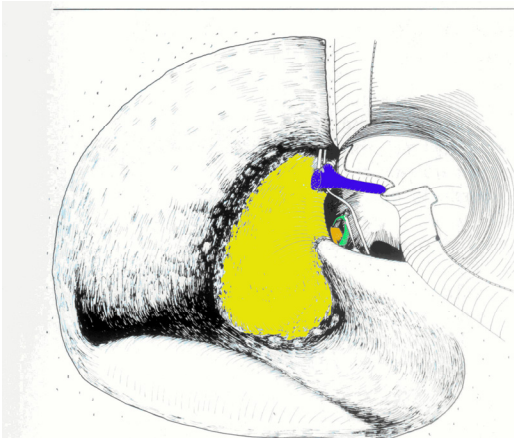


Fig 9 showing a small atticotomy

Bondy's Operation: (Fig 10)

This is nothing but atticotomy without entering the tympanic cavity. The lateral part of the cholesteatoma matrix is removed; the medial part is left in place marsupializing the cholesteatoma. If the tympanic cavity is entered the operation is not described as Bondy's operation, but as an atticotomy or conservative radical operation.

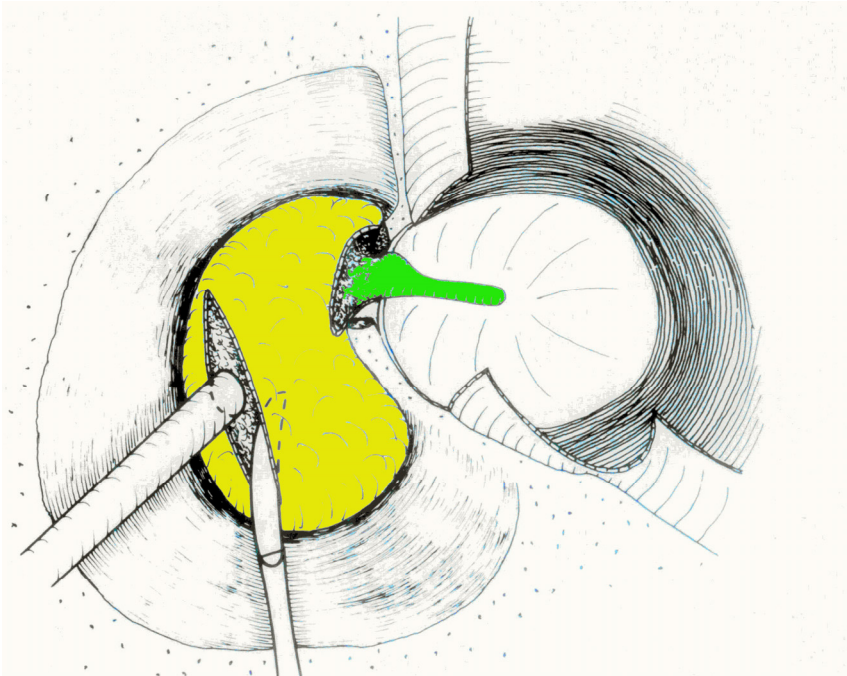


Fig 10 showing Bondy's operation

In classic Bondy's operation atticoantrostomy with removal of the posteriosuperior bony meatal wall is performed exposing the cholesteatoma sac involving the attic and antrum. The sac is then incised, a suction tube is placed in the sac, and the cholesteatoma mass is sucked away. The lateral part of the matrix is then cut off.

If the tympanic cavity is opened and the cholesteatoma marsupialized with the matrix being left in place in the attic, the fascia has to be placed under the matrix in order to prevent in growth of the cholesteatoma into the tympanic cavity. The keratinized squamous epithelium of the matrix and the epithelium of the replaced drum remnant and the canal skin gets integrated.

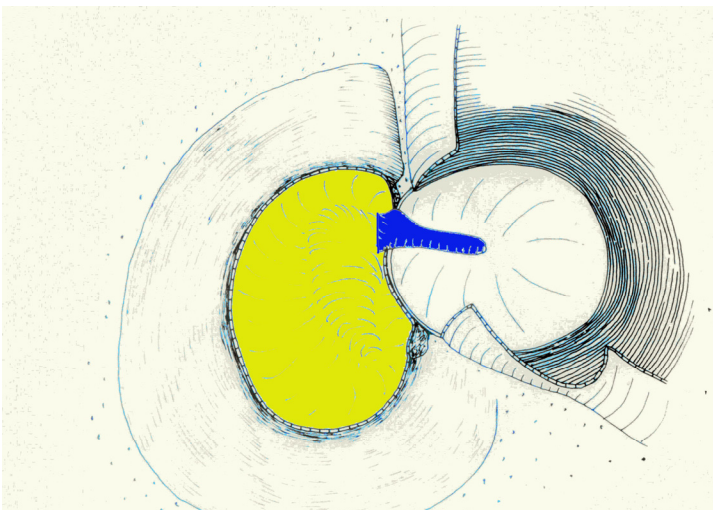


Fig 11 showing completed Bondy's operation, with the atticoantrostomy. The malleus & incus are intact, but covered with cholesteatoma matrix.

If there is no need for hearing improvement and ossiculoplasty, the tympanic cavity is not opened in Bondy's operation, whereas in conservative attico antrostomy a tympanoplasty is also performed, either to prevent in growth of the cholesteatoma into the tympanic cavity or as a part of ossiculoplasty.

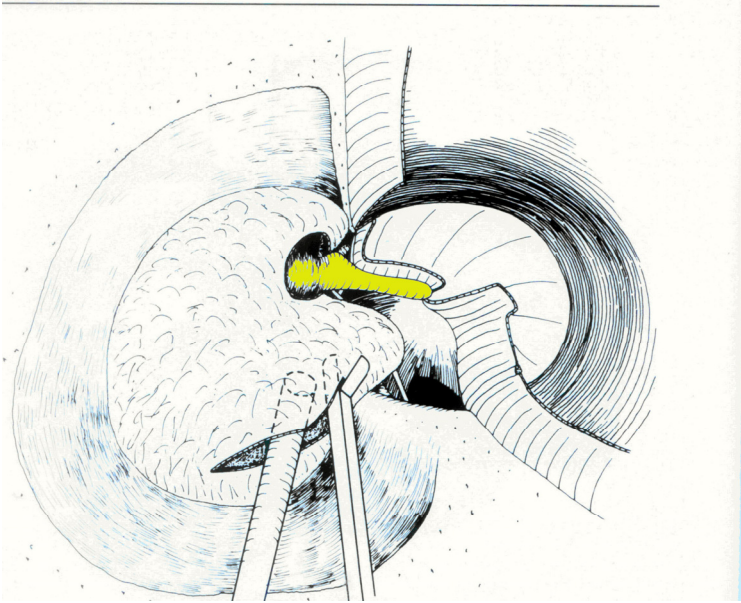


Fig 12 showing atticoantrostomy, or conservative radical operation, with marsupialization of an attic cholesteatoma extending into the tympanic cavity, which is open. The sac is incised, and the cholesteatoma is sucked out. The tympanic cavity is entered, with the tympanomeatal flap being elevated posteriorly.

In the treatment of attic cholesteatoma, a gradual transition from an atticotomy with removal of the bony bridge to Bondy's operation can be seen. In fact, it is only the extent of bone removal from the posterosuperior ear canal wall and the adherence of the cholesteatoma membrane to the lateral semicircular canal, with blockage of the ventilation through the tympanic isthmus that distinguishes a large atticotomy from a small Bondy's operation. In both types, the medial part of the cholesteatoma sac is left in place covering the intact Ossicular chain, or the medial wall of the aditus ad antrum with the lateral semicircular canal and the medial wall of the antrum.

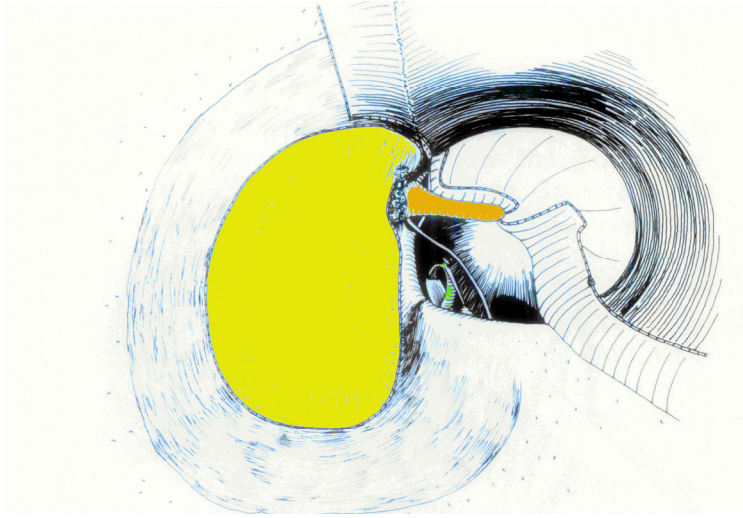


Fig 13. After removal of the partly eroded incus, and after resection of the head of the malleus, the medial part of the cholesteatoma matrix is left in place. The cholesteatoma is marsupialized in the attic and antrum regions, but removed from the tympanic cavity.

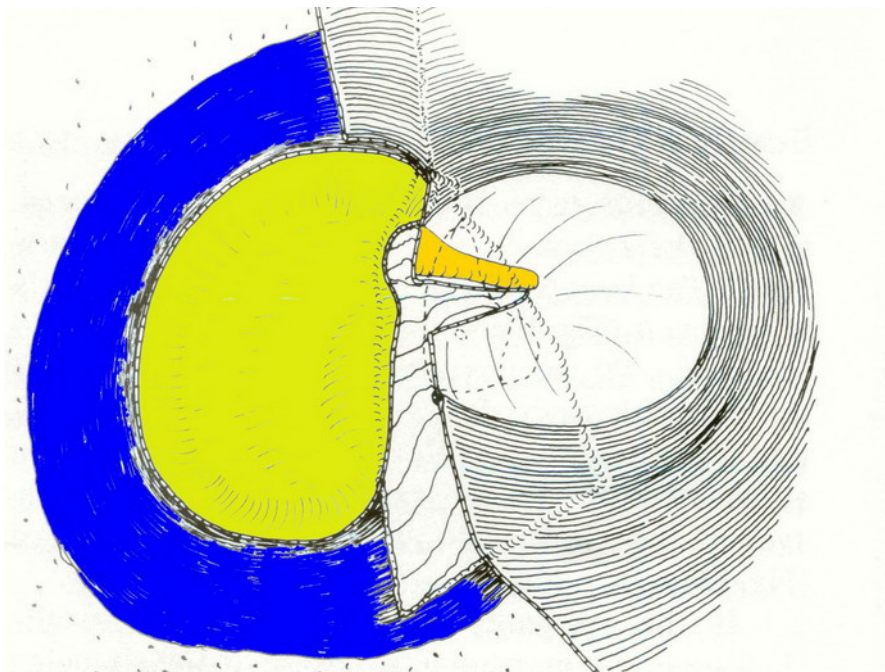


Fig 14 After the incus interposition between the stapes and the malleus handle, after placement of the fascia under the epithelial edges and under the drum, and after replacement of the skin flaps, the conservative operation is completed.

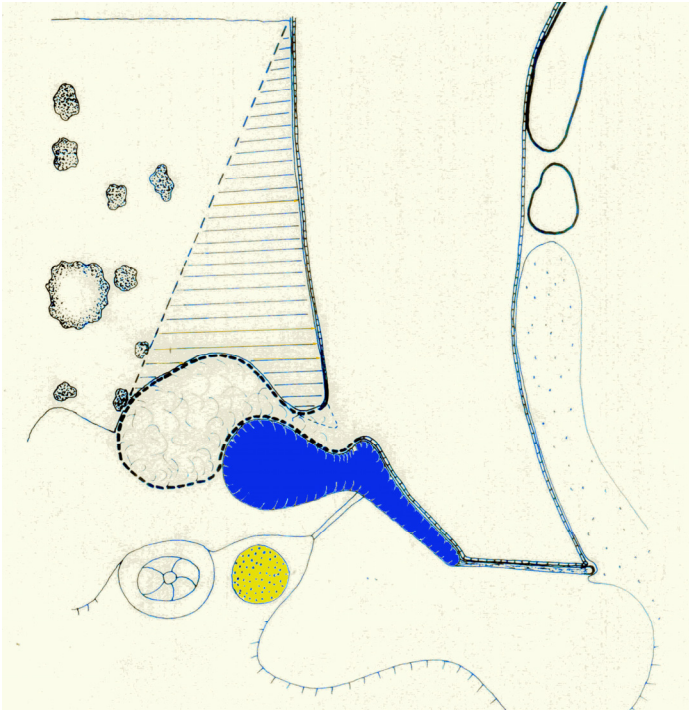


Fig 15 Side view of an atticotomy with removal of the scutum and the bony bridge (hatched area)

In cases with a small attic cholesteatoma, good hearing, and no significant discharge, and in which the bottom of the cholesteatoma cannot be seen, an atticotomy can be performed by removing the scutum until the bottom is visible i.e. fig 15. The lateral wall of the cholesteatoma sac is removed, and the medial wall is left in place, improving access to the cholesteatoma sac and facilitating migration of the keratin from the sac.

In an attic cholesteatoma involving the aditus ad antrum, a large part of the postero superior bony canal has to be drilled in order to perform a large atticotomy and marsupialize the cholesteatoma. Ventilation of the antrum still occurs through the tympanic isthmus under the body of incus and the head of the malleus and under the medial part of the cholesteatoma matrix, which is not adherent to the lateral semicircular canal. The adherence of cholesteatoma membrane to the lateral semicircular canal is probably the most reliable sign differentiating the atticotomy from the Bondy's operation in cases of attic cholesteatoma. In cases with adherence of the cholesteatoma membrane to the lateral canal the aditus ad antrum is involved in the cholesteatoma, and ventilation of the antrum cannot take place through the tympanic isthmus. Extensive removal of bone is necessary to visualize the cholesteatoma sac, and the result resembles a small open atticostomy cavity - a Bondy's operation.

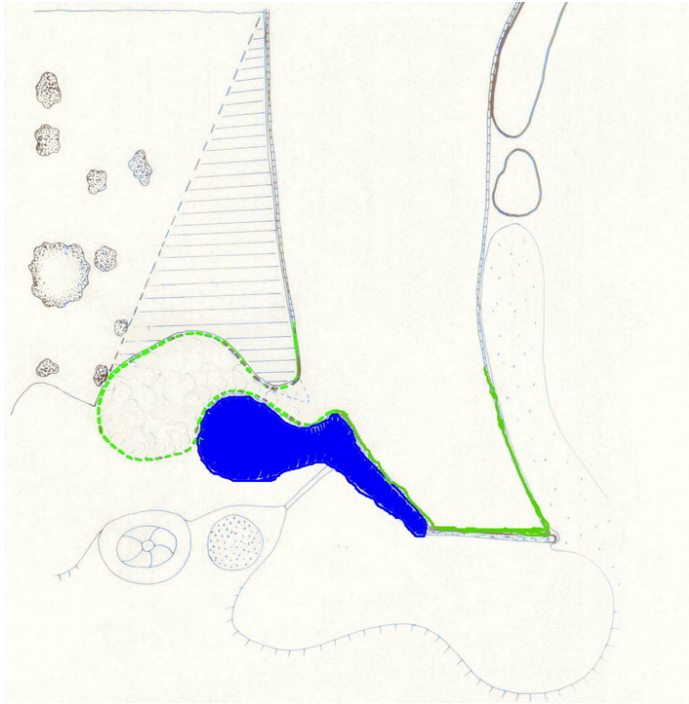


Fig 16 Side view of an atticotomy with large removal of the superior bony ear canal wall (hatched area) ventilation of the antrum through the isthmus is still possible.

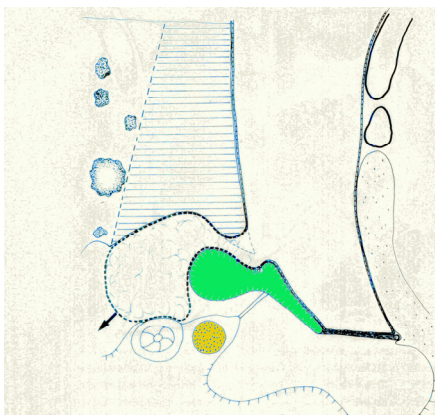


Fig 17 Side view of a large atticotomy or a small Bondy's operation in an attic cholesteatoma involving the aditus ad antrum, adherent to the lateral canal closing the isthmus, blocking the ventilation of the antrum. Even after removal of the large part of

the superior bony canal wall (hatched area) and the lateral membrane of the cholesteatoma sac (dashed line) with good exposure of the medial cholesteatoma wall, progression of the cholesteatoma is possible towards the antrum indicated by the arrow.

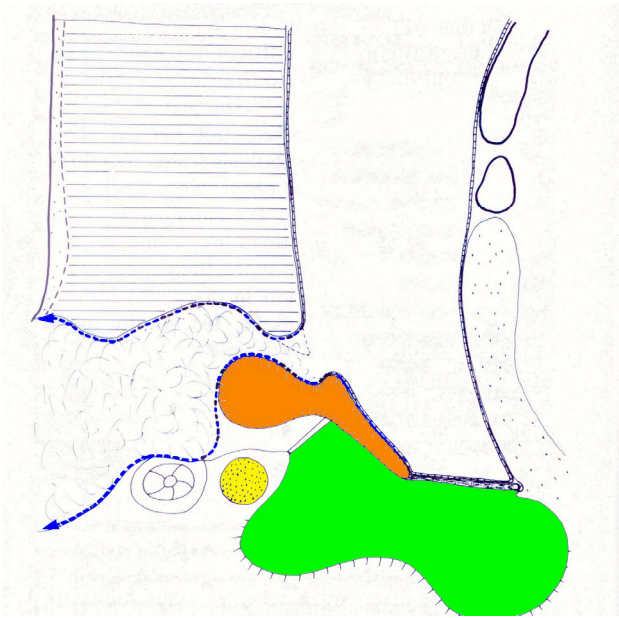


Fig 18 Side view of a Bondy's operation in a case with large attic cholesteatoma. All bone from the postero superior canal wall up to the middle fossa dura is removed (hatched area), together with the lateral membrane of the cholesteatoma sac (dashed line). The cholesteatoma is marsupialized, with wide access to the small open cavity. The Ossicular chain is intact, and the medial cholesteatoma membrane is adherent to the medial aditus and antrum walls.

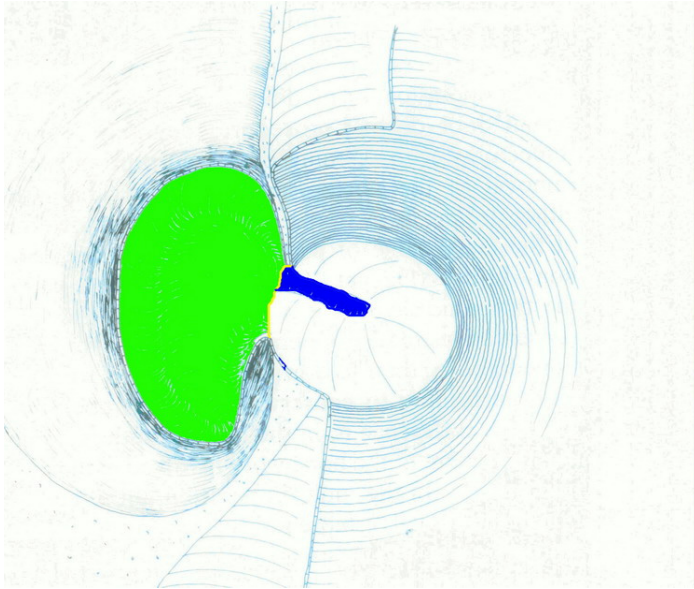


Fig 19 Large atticotomy with removal of bony bridge in an attic cholesteatoma. Extensive drilling of the superior canal wall is performed, and the cholesteatoma is marsupialized. The medial wall of the cholesteatoma sac covers the head of the malleus and the body of the incus. The cholesteatoma is not adherent to the lateral wall of the semicircular canal, providing good ventilation of the antrum through the tympanic isthmus.

Cortical Mastoidectomy (Schwartz Mastoidectomy) is a transcortical opening of the mastoid cells and the antrum. It is the initial stage of any transmastoid surgery of the middle ear, inner ear, facial nerve, endolymphatic sac, labyrinth, internal acoustic meatus, and various procedures on the skull base for removing skull base tumors.

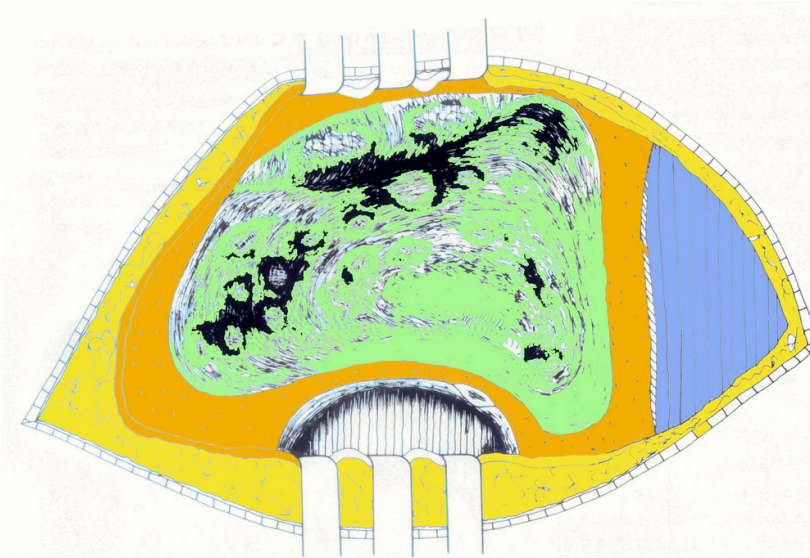


Fig 20 Simple cortical Mastoidectomy in a retro auricular approach. The antrum and the mastoid cells are opened. The bony meatal wall is intact but thick, because the small cells of the ear canal have not been removed. The lateral canal, the malleus, and the incus are just visible. The outer attic wall is not opened.

Conservative Radical Operation

Conservative radical Mastoidectomy, conservative radical operation, or modified radical operation is a canal wall down procedure, denoting a Mastoidectomy with opening of the antrum and attic, removal of the postero superior bony canal wall, either drilling away of the bony bridge and lowering of the facial ridge or preserving the thinned down bony ridge. The structures within the tympanic cavity are preserved, hence the term conservative radical operation. The only difference between this and the attico antrostomy is the extent of bone removal. In the radical operation, the exenteration of the air cells is more radical than in an attico antrostomy. Also, marsupialisation of the cholesteatoma and leaving intact the medial part of the cholesteatoma membrane is not included in conservative radical operation.

DEFINITIONS:

BRIDGE: is a part of bony postero superior meatal wall lateral to aditus ad antrum.

Facial Ridge: It is a bony posterior meatal wall that lies lateral to vertical portion of facial nerve.

Anterior Buttress: is that part of the bone where the posterior canal wall meets the tegmen.

Posterior Buttress: is that part of the bone where posterior canal wall meets the floor of the external auditory canal lateral to the facial nerve.

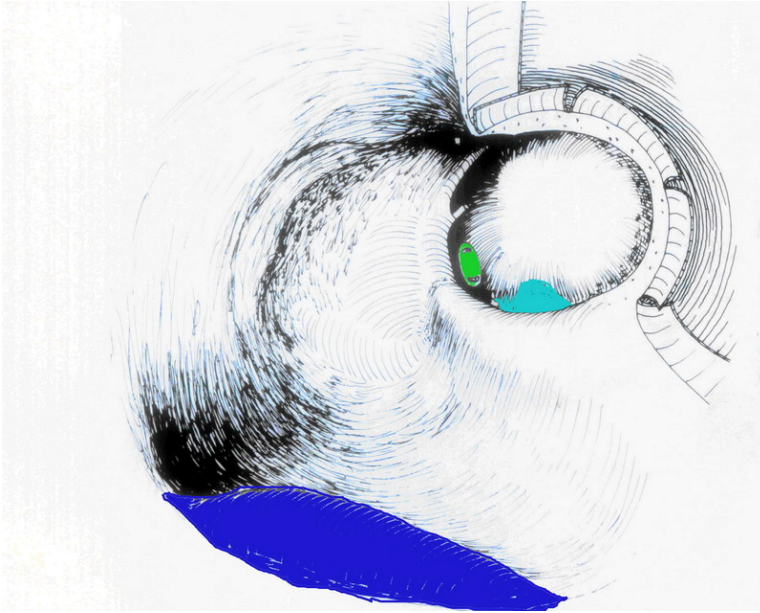


Fig 21 Situation in the tympanic cavity after a classical radical Mastoidectomy with removal of the fibrous annulus and all ossicles. The cavity is large, the facial ridge is low.

Classical Radical Operation:

Classical radical Mastoidectomy or classical radical operation is a canal down Mastoidectomy, and includes the same bone work in the mastoid process as the conservative radical operation. However, the structures within the tympanic cavity are removed, e.g. the remnants of the incus and malleus, and the drum remnant with the fibrous annulus and sometimes even the bony annulus. In a classical radical operation closure of the eustachean tube is performed. Today even after radical removal of all structures from the tympanic cavity, an attempt to close the tympanic cavity is performed to achieve faster healing, or sometimes even to reventilate the tympanic cavity, or at least a part of it.

Tympanomastoidectomy:

Transmastoid tympanoplasty, tympanomastoidectomy, combined approach tympanoplasty or cortical Mastoidectomy, are terms denoting an intact canal wall or canal wall up Mastoidectomy where the posterior canal wall is preserved. The procedure is based on retro auricular approach.

Several methods of Mastoidectomy are used: 1. classic intact canal wall
2. Modifications of intact canal wall procedures, 3. Temporary displacement or removal of bony ear canal.

Approaches and Routes:

The term approach means the method of access to the middle ear through soft tissues; the term route means the method of access to the middle ear through the bone. The approaches can be endaural, or retro auricular, and superior or anterior.

The routes can be transcortical or transmeatal.

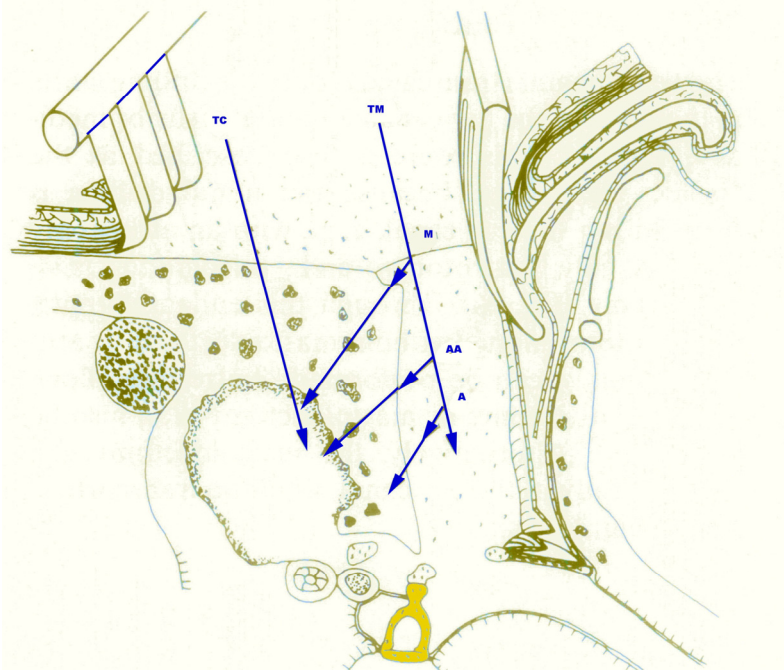


Fig 22 The transcortical and transmeatal routes for a Mastoidectomy in the retroauricular approach. The ear canal skin is pushed anteriorly, and its superior part is elevated. The bone work can be performed by a transcortical (outside - in) route or a transmeatal one (inside - out). The transcortical TC and transmeatal TM routes are indicated as well as the transmeatal routes for atticotomy A, atticoantrostomy AA and Mastoidectomy M. The dark dotted area is the sigmoid sinus.

Transcortical route:

The transcortical route for drilling starts on the surface of the cortical bone of the mastoid process, behind the bony ear canal, which can remain intact either temporarily or permanently. This route is also described as the outside in route, because the initial drilling is always outside.

Transmeatal route:

The transmeatal (transcanal) route for drilling starts in the bone of the ear canal, either laterally or medially. This route is also described as the inside out route, because the initial drilling is from within the ear canal, e.g., with an atticotomy followed by antrostomy and retrograde Mastoidectomy. Through this endaural route, an atticotomy alone without Mastoidectomy can be performed. The Mastoidectomy can start in the ear canal, as in the transcortical route.

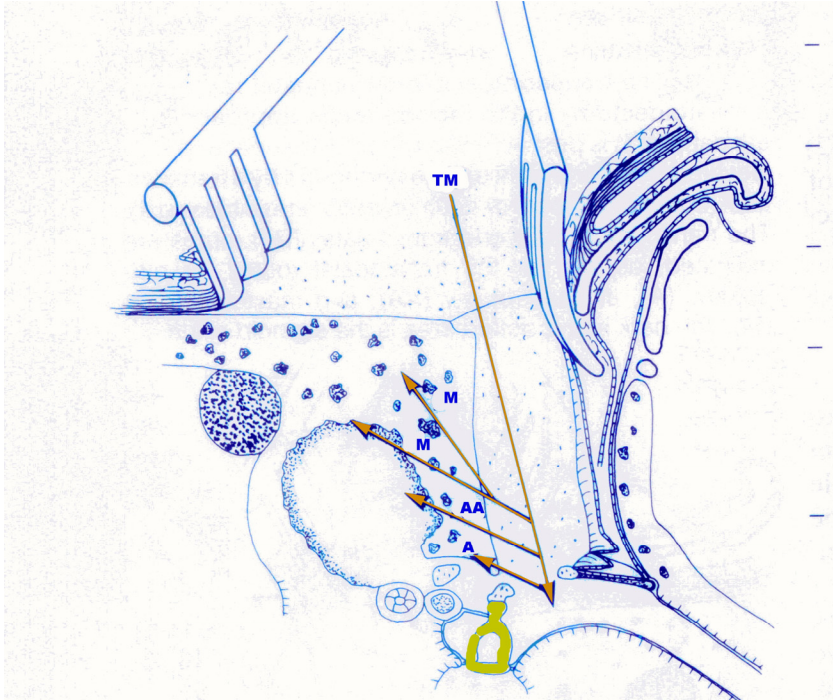


Fig 24 The retrograde Mastoidectomy in a retroauricular approach and transmeatal TM route.

First an atticotomy A is performed and continued posterolaterally, entering the antrum with an atticotomy AA and further removal of mastoid air cells laterally and posteriorly resulting in a retrograde Mastoidectomy M. A typical inside out Mastoidectomy.

Approaches and mastoidectomies:

In Mastoidectomy, both the endaural and the retro auricular approaches have various advantages and disadvantages.

1. The view into the attic in the retroauricular approach is oblique, in the posteroanterior direction. In the endaural approach, the view is direct, lateromedially, and the distance to the attic is shorter than in the retroauricular approach.
2. The view into the Eustachian tube orifice is good in both approaches, but somewhat better in the retroauricular approach.
3. The view into the posterior tympanum and sinus tympani is better in the endaural than in the retro auricular approach.
4. Mastoidectomy can easily be extended in the retroauricular approach, whereas extension is difficult or even impossible in the endaural approach.

5. Cavity obliteration with muscle flaps, especially using the anterior based Palva flap and the inferiorly pedicled Guilford flap are only possible in the retroauricular approach.

The retroauricular approach is increasingly dominating mastoid surgery, partly because of the ease of cavity obliteration and better access it provides.

Routes and approaches:

Using the retroauricular approach, both the transcortical and the transmeatal routes to the mastoid for canal wall up Mastoidectomy, atticoantrostomy, and canal wall down Mastoidectomy can be used. In fact, the transmeatal route can be employed as easily as the transcortical route. With the endaural approach, the Transmeatal route is the route of choice.

An atticotomy usually starts with drilling of the lateral attic wall, and a transmeatal atticoantrostomy follows the atticotomy through further drilling of the ear canal wall. Mastoidectomy or a conservative radical operation can then be performed as a retrograde extension of the atticoantrostomy.

The cavities produced using the retroauricular approach, either by transcortical or the transmeatal route, are generally larger than the cavities produced using the endaural approach.

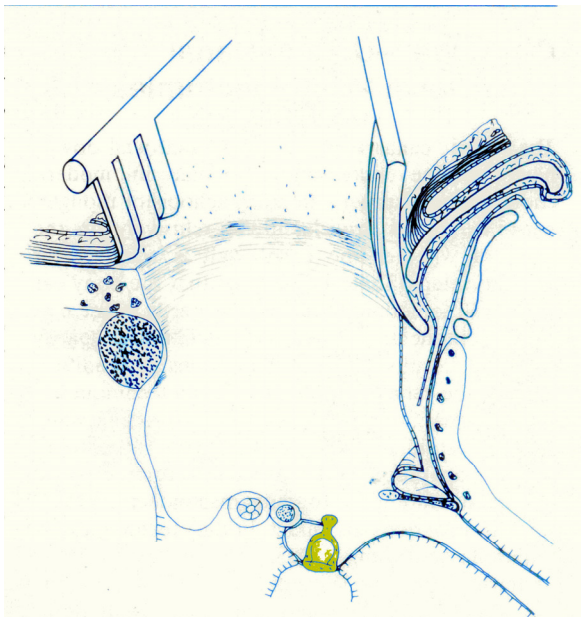


Fig 25 Side view of the mastoid cavity obtained in a retroauricular approach with extensive drilling of the cortical bone at the mastoid plane. Medially, the lateral semicircular canal, facial nerve, stapes and malleus handle, with the anterior aspect of the drum are shown.

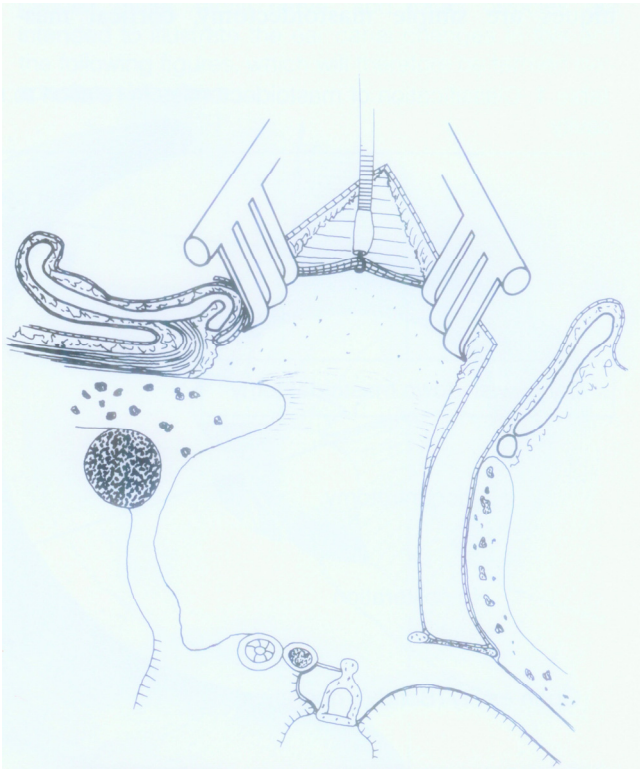


Fig 26 The cavity usually achieved in an end aural approach with less extensive drilling of the cortical bone at the mastoid plane. The dark dotted area is the sigmoid sinus.

Canal wall up and canal wall down mastoidectomies:

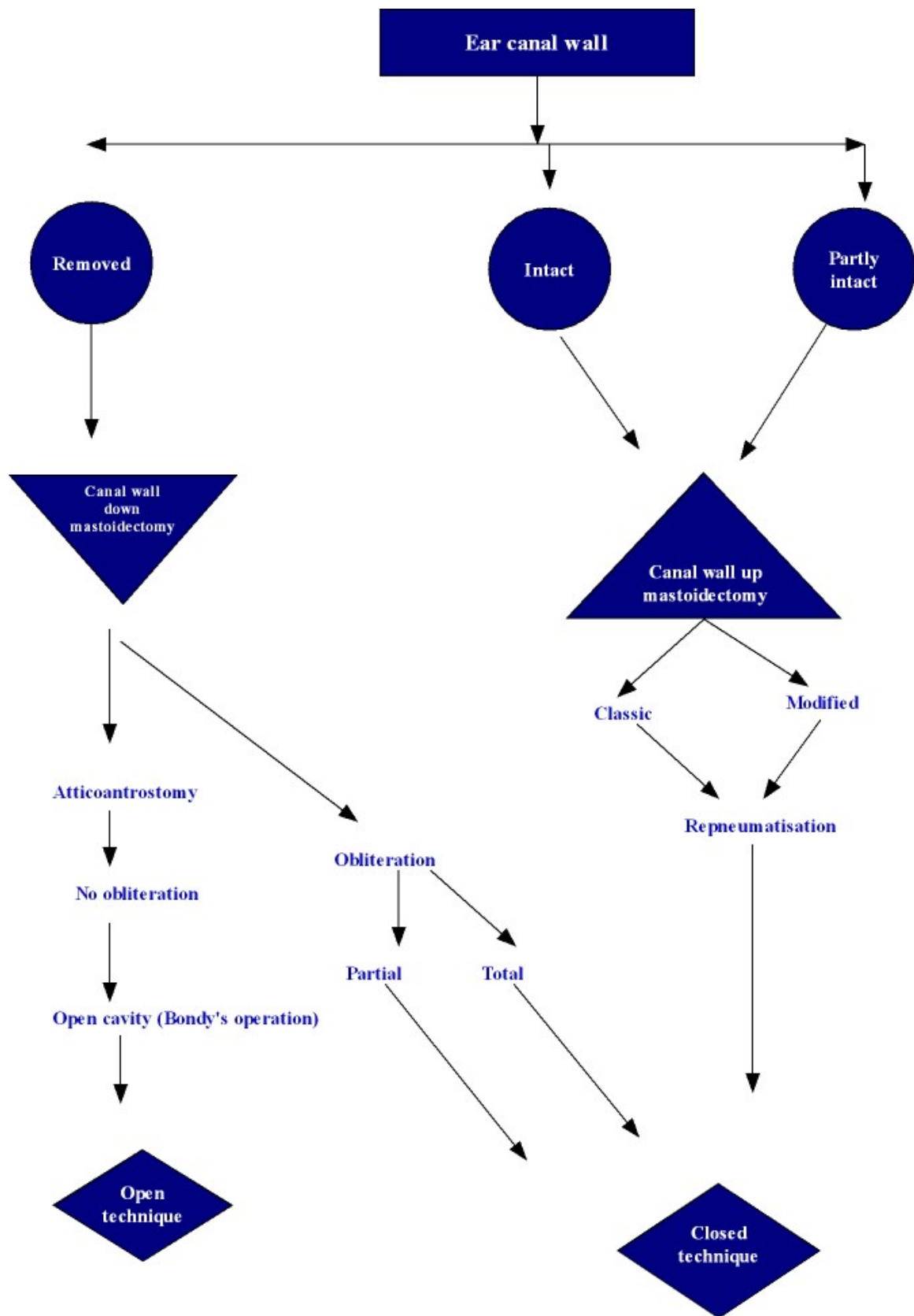
The terms canal wall up and canal wall down have become popular. Mastoidectomies are classified exclusively on the basis of whether the canal wall is removed or remains intact. Table 1. The fact that the bony ear canal wall sometimes remains only partly intact, e.g., after spontaneous erosion, or is deliberately partly removed, results in several variations or modifications of the canal wall Mastoidectomy techniques.

Subclassification of, or synonyms for canal wall down Mastoidectomy techniques are: atticotomy, Bondy's operation, atticoantrostomy, classical radical operation, retrograde Mastoidectomy.

The subclassifications of canal wall up techniques are simple Mastoidectomy, cortical Mastoidectomy, classic intact canal wall Mastoidectomy, CAT.

The other features of the classification are the obliteration of the cavity or reconstruction of the ear canal or both.

Open technique: In canal wall down Mastoidectomy, the cavity may remain open, neither obliterated nor with the ear canal reconstructed. The exposed bone is simply covered with fascia or skin or not covered at all. This type of cavity is lined by granulations and later reepithelialized.



Closed technique: The canal wall down Mastoidectomy cavity can be partly or totally obliterated, and the ear canal partly or totally reconstructed. A partly or totally reconstructed canal wall down cavity is defined as the closed technique.

Classic canal wall up Mastoidectomy:

Also known as classic intact canal wall Mastoidectomy or CAT is defined as a Mastoidectomy with an entirely preserved, but thinned, bony ear canal wall. The disease from the attic is removed through careful drilling of all the bone between the ear canal and the tegmen tympani and hence enlarging access to the attic. Access to the tympanic cavity is achieved by a so called posterior tympanotomy other wise also known as posterior atticotomy. The goal of the intact canal wall Mastoidectomy is to repneumatize the mastoid cavity.

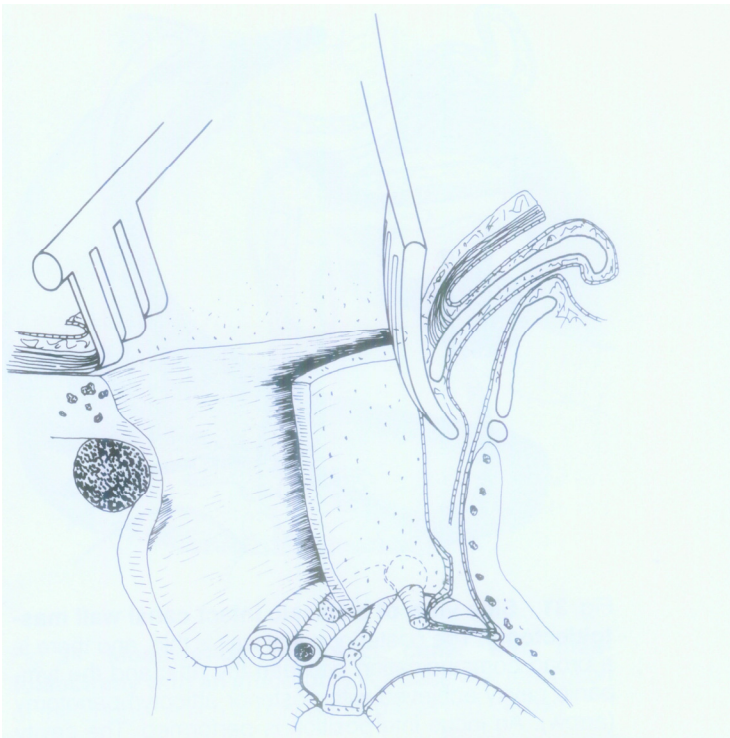


Fig 27 Perspective side view of the intact canal wall Mastoidectomy in a retroauricular approach on the superior half of the cavity. The ear canal, lateral semi circular canal, facial nerve, and intact ossicles are intended to illustrate the ear canal changes in this.

Several modifications of intact canal wall Mastoidectomy have been described and used, but in several so called intact canal wall methods, the bony ear canal is not intact at all, partly because of the extensive drilling of the medial ear canal wall, and partly because of the spontaneous resorption of the lateral attic wall.

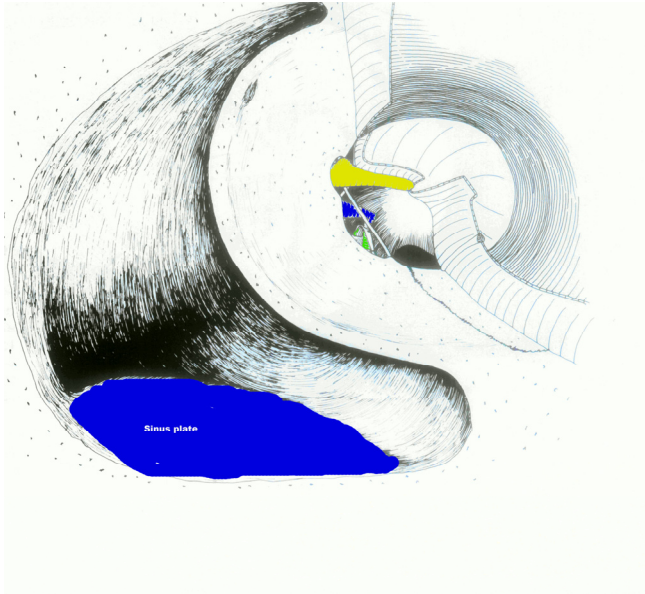


Fig 28 The classic intact canal wall Mastoidectomy with an entirely intact, but thinned, bony ear canal wall

Modifications of intact canal wall Mastoidectomy:

1. Atticotomy with preservation of the intact bony bridge
2. Atticotomy with preservation of a partly resorbed bony bridge
3. Atticotomy with removal of the bridge
4. Widening of the ear canal

Atticotomy openings of various sizes with preservation of the intact nonresorbed bony bridge:

The goal of this atticotomy is to obtain a good view into the anterior attic. The bridge remains in its normal position. (Fig 30)

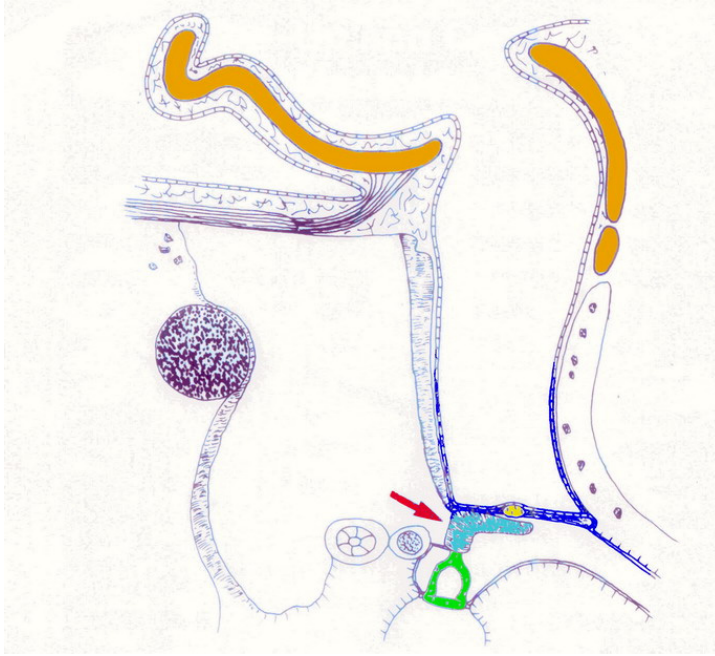


Fig 29 Side view of classic intact canal wall Mastoidectomy. The posterior wall is thin, and there is a broad communication between the attic and tympanic cavity through posterior atticotomy indicated by the arrow. Incus repositioning is performed and the cavity will be repneumatized.

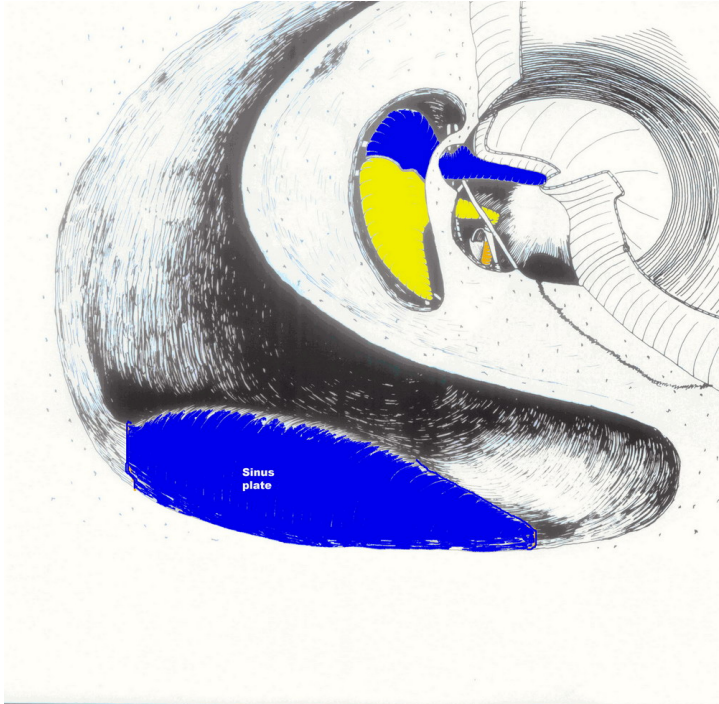


Fig 30 Modification of intact canal wall Mastoidectomy with an atticotomy. The bridge is preserved with good view of the attic.

Atticotomy openings of various sizes with preservation of a partly resorbed bony bridge:

In cases in which there is spontaneous resorption of the lateral attic wall due to cholesteatoma, an atticotomy has to be performed superiorly to the resorbed bridge, resulting in displacement of the new bridge superiorly and laterally. Sometimes, resorption of the lateral wall can be more extensive, so that the atticotomy has to be performed further laterally, and the bony bridge in such cases is displaced further superolaterally. (Fig 31)

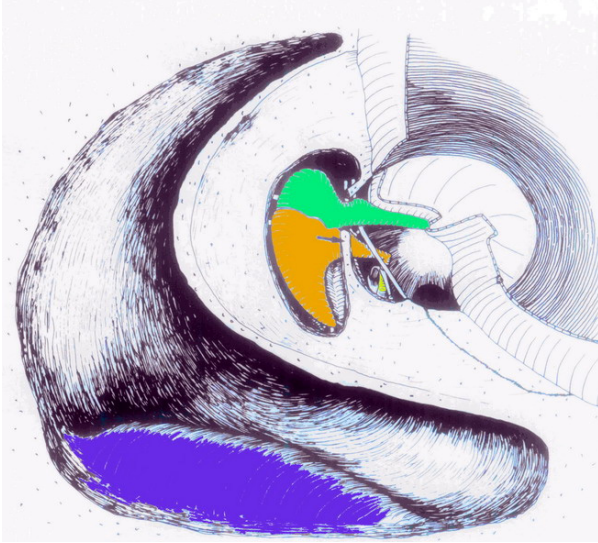


Fig 31 Modification of intact canal wall Mastoidectomy with an atticotomy in a case with resorption of the bridge, which is only partially preserved. (arrow)

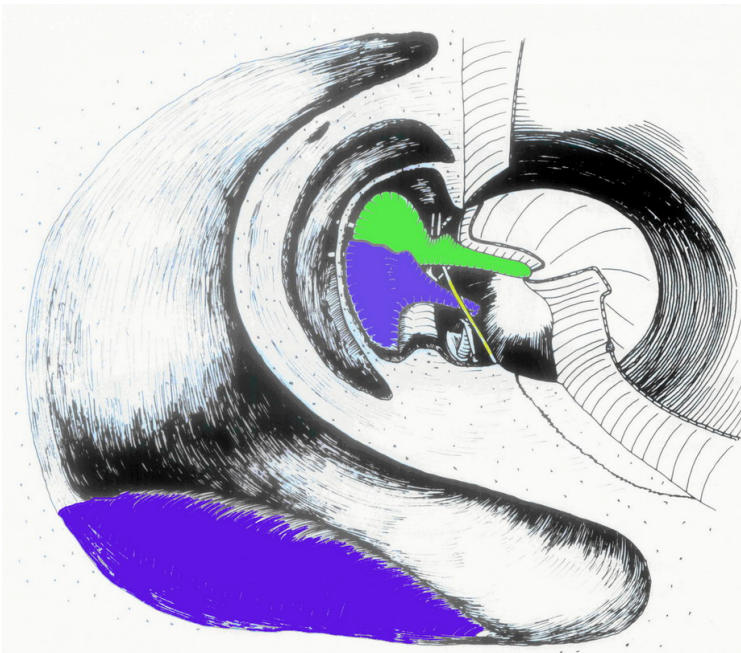


Fig 32 A high atticotomy in a case with extensive spontaneous resorption of the lateral attic wall. The atticotomy is extended posteriorly towards the antrum. The bridge is displaced superolaterally.

Atticotomy openings of various sizes with removal of bony bridge:

Removal of the lateral attic wall is known as anterior tympanotomy. In cases with resorption of the lateral attic wall, only limited removal of the bridge is necessary. After

extensive removal of the lateral attic wall and a large atticotomy, only the lateral half of the ear canal wall is intact.

Widening of the ear canal:

By drilling the lateral part of the canal, better access to the tympanic cavity can be achieved. The superior wall of the ear canal can be drilled away, exposing the lateral attic, the tegmen antri, and the tegmen tympani. With continued drilling of the ear canal, an attico antrostomy can be performed resulting in the entire canal wall being displaced posteriorly in relation to its normal position, with the attic being exposed.

The bridge can be preserved or removed. Usually the Ossicular chain is not intact.

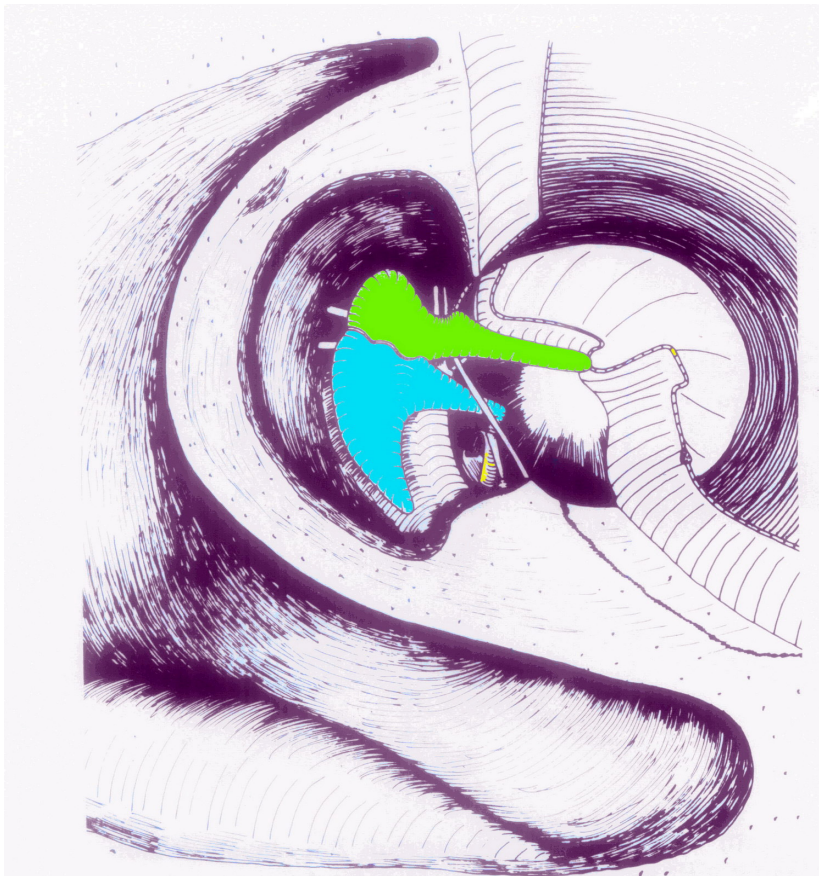


Fig 33 Canal wall up Mastoidectomy with a large atticotomy posteriorly involving the antrum as well.

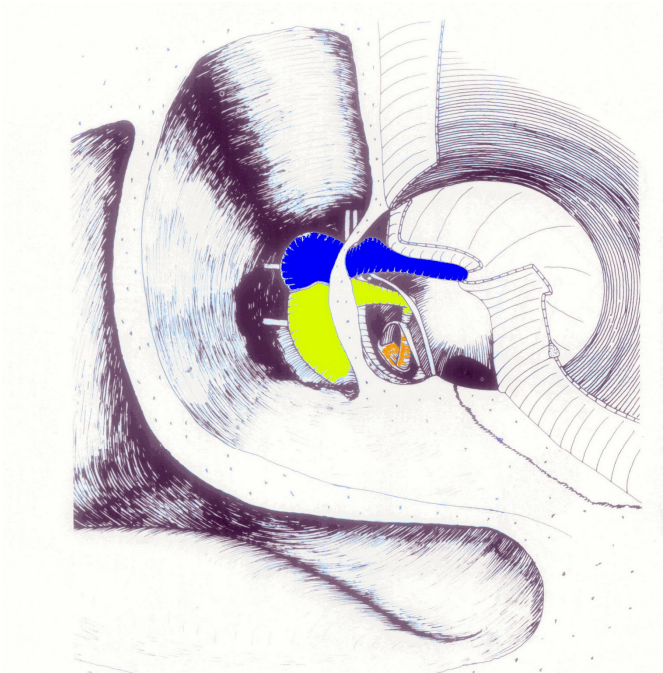


Fig 34 Widening of the lateral part of the ear canal combined with an atticotomy with preservation of the bridge. The entire ear canal is displaced superoposteriorly, and behind it a Mastoidectomy is performed.

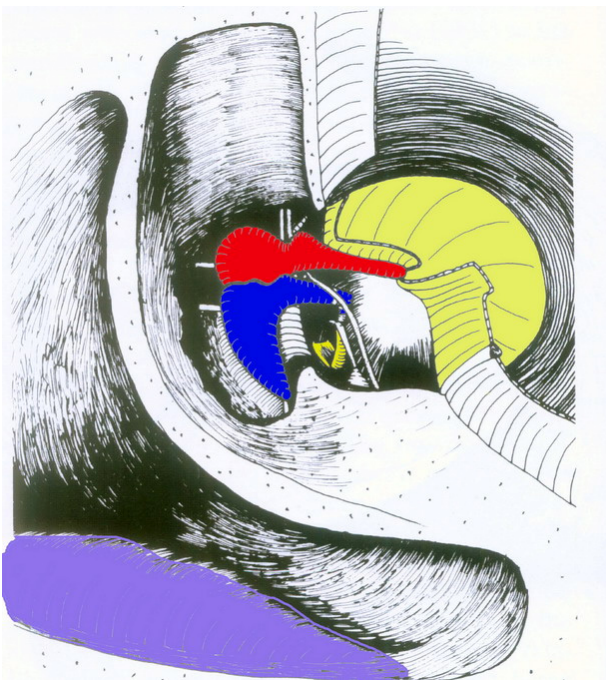


Fig 35 Widening of the ear canal with atticotomy and Mastoidectomy, without bridge preservation.

Canal wall down Mastoidectomy:

The canal wall down mastoidectomies include attico antrostomy, Bondy's operation and conservative and classic radical mastoidectomies with total removal of bony bridge.

Modifications of canal wall down Mastoidectomy:

Modifications are related to the preservation or partial preservation of the bony bridge, resulting in intact bridge techniques. In cases with resorption of the lateral attic wall, the bridge can be preserved, but is displaced laterally and posteriorly.

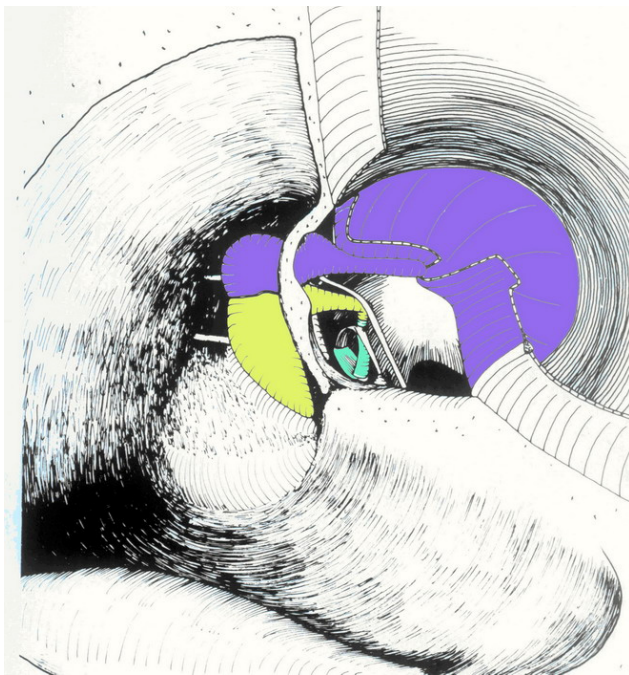


Fig 36 Modification of canal wall down Mastoidectomy with the preserved bridge in its normal position.

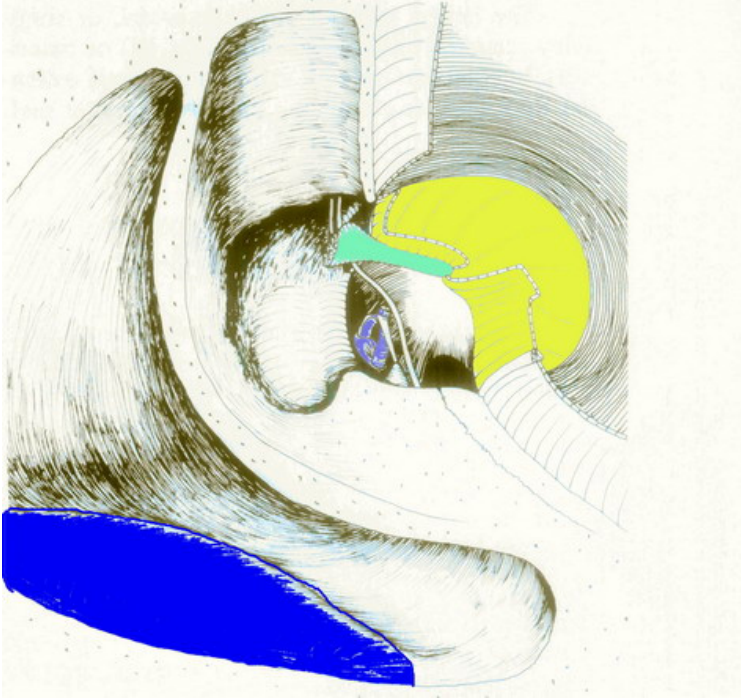


Fig 37 Widening of the ear canal, atticotomy, and Mastoidectomy in a situation without the incus and malleus head.

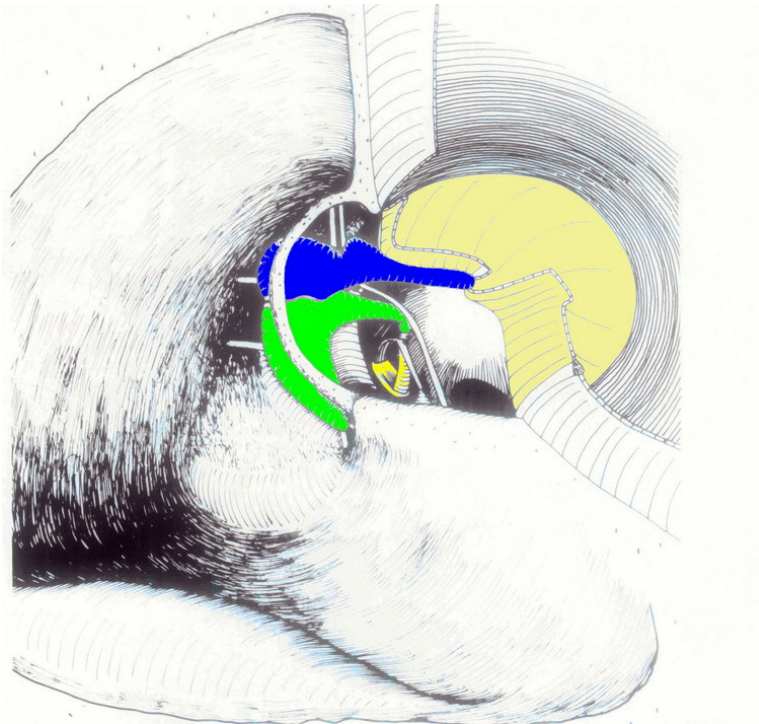


Fig 38 Canal wall down Mastoidectomy with preservation of the bridge in a case with spontaneous erosion of the lateral attic wall, resulting in the bridge being displaced laterally and posteriorly.

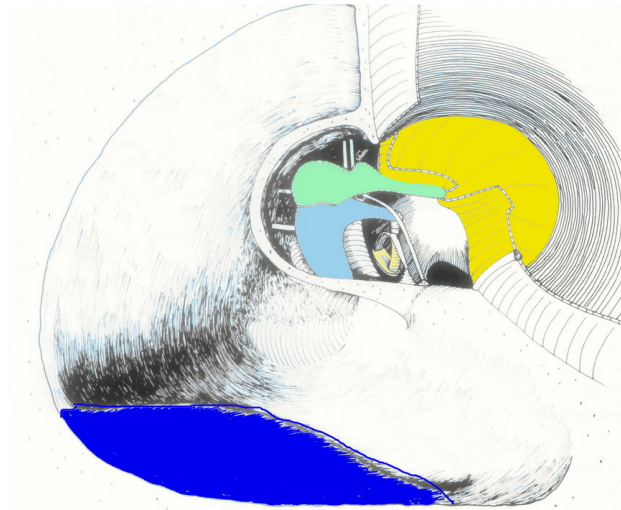


Fig 39 Canal wall down Mastoidectomy with preservation of the bridge, which is displaced laterally and posteriorly in relation to the incus and malleus.

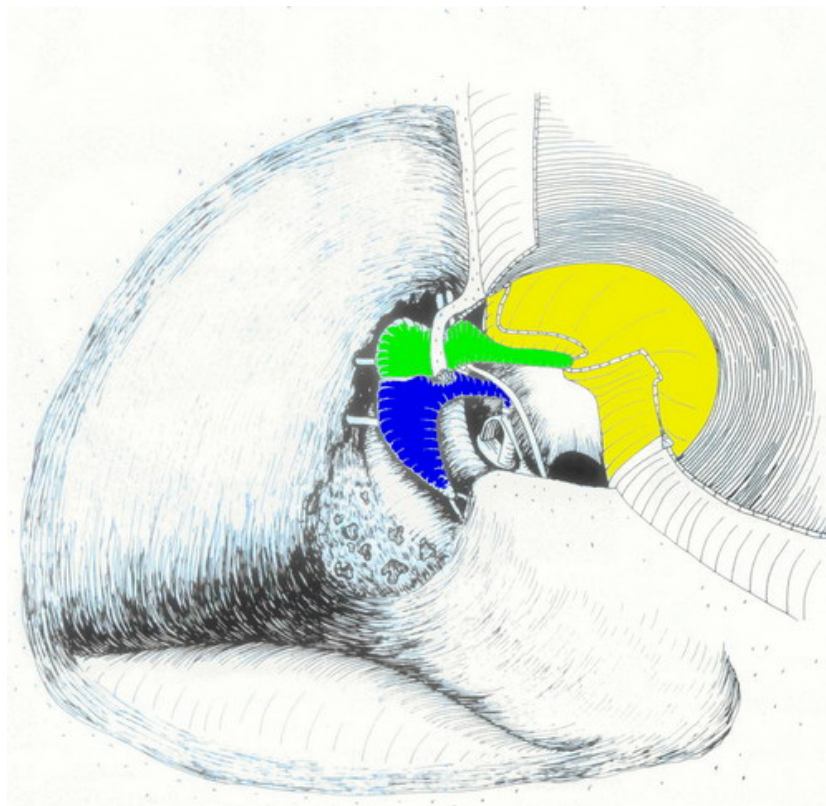


Fig 40 Canal wall down Mastoidectomy with partial preservation of the bridge in a case with partial preservation of the bridge in a case with spontaneous resorption of the bridge.

The bridge may be partly resorbed, or surgically removed either posteriorly or anteriorly. In combination with various degrees of Ossicular deficiency (e.g., missing incus but

present malleus, or missing incus and malleus head) and various types of partial bridge removal have been described.

Tympanoplasty:

The fundamental principles of Tympanoplasty were introduced by Zollner and Wullstein. These principles were directed towards restoration of middle ear function as well as ensured trouble free and stabilized ear.

Wullstein and Zollner classified Tympanoplasty according to the type of ossicular reconstruction needed. Five types of Tympanoplasty have been classified.

Type I Tympanoplasty: This is indicated in patients with presence of all the middle ear ossicles with normal mobility. Ossicular chain reconstruction is not needed in these patients. Efforts are made to close the perforated ear drum using temporalis fascia graft (Hong Kong flap). This procedure is also known as myringoplasty.

Advantages of using temporalis fascia as graft material:

1. It is an autograft with excellent chance of take
2. It is available close to the site of operation making its harvest easier
3. It has a low basal metabolic rate, brightening its success rate
4. Its thickness is more or less similar to that of tympanic membrane

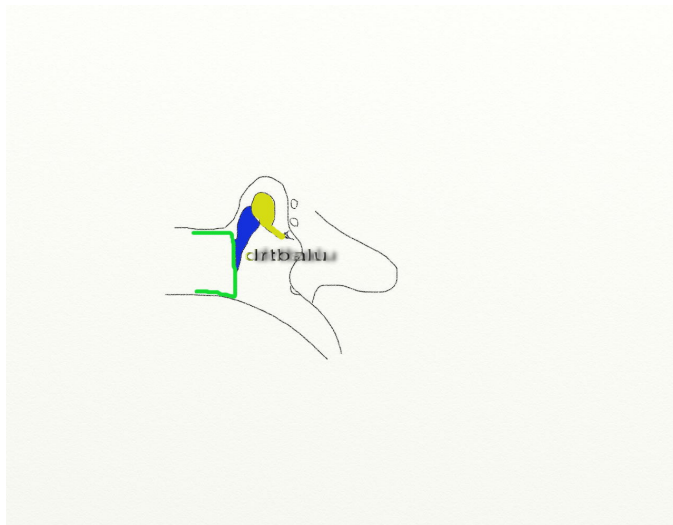


Figure showing Type I Tympanoplasty

There are two available techniques for performing myringoplasty / type I Tympanoplasty.

1. Overlay technique
2. Under lay technique

Overlay technique: This is a difficult technique to master. Here the graft material is inserted under the squamous (skin layer) of the ear drum. It is a difficult task peeling only the skin layer away from the tympanic membrane, placing the graft over the perforation and redraping the skin layer.

Underlay technique: This is a simpler and commonly used technique. Here the graft is placed under the tympano meatal flap which has been elevated hence the name under lay. The major advantage of this procedure is that it is easy to perform with a good success rate.

Indications of Myringoplasty:

1. Central perforation which has been dry at least for a period of 6 weeks.
2. As a follow up to mastoidectomy procedure to recreate the hearing mechanism

Prerequisites for myringoplasty:

1. Central perforation which has been dry for at least 6 weeks
2. Presence of normal middle ear mucosa
3. Intact ossicular chain
4. Good cochlear reserve

Procedure: Firstly a temporalis fascia of adequate site must be harvested and allowed to dry.

The surgery is performed under local anesthesia. Temporalis fascia graft is harvested under local anesthesia conventionally and allowed to dry. The external auditory canal is then anesthetized using 2 % xylocaine mixed with 1 in 10,000 adrenaline injection.

About 1/2 cc is infiltrated at 3 - o clock, 6 - o clock, 9 - o clock, and 12 - o clock positions about 3mm from the annulus. The patient is premedicated with intramuscular injections of 1 ampoule fortwin and 1 ampoule phenergan.

Step I: Freshening the margins of perforation - In this step the margins of the perforation is freshened using a sickle knife or an angled pick. This step is very important because it breaks the adhesions formed between the squamous margin of the ear drum (outer layer) with that of the middle ear mucosa. These adhesions if left undisturbed will hinder the take up of the neo tympanic graft. This procedure will in fact widen the already present perforation. There is nothing to be alarmed about it.

Step II: This step is otherwise known as elevation of tympano meatal flap. Using a drum knife a curvilinear incision is made about 3 mm lateral to the annulus. This incision ideally extends between the 12 - o clock, 3 - o clock, and 6 - o clock positions in the left

ear, and 12 - o clock, 9 - o clock and 6 - o clock positions in the right ear. The skin is slowly elevated away from the bone of the external canal. Pressure should be applied to the bone while elevation. This serves two purposes:

1. It prevents excessive bleeding
2. It prevents tearing of the flap.

This step ends when the skin flap is raised up to the level of the annulus.

Step III: Elevation of the annulus and incising the middle ear mucosa. In this step the annulus is gradually lifted from its rim. As soon as the annulus is elevated a sickle knife is used to incise the middle ear mucosal attachment with the tympano meatal flap. This is a very important step because the inner layer of the remnant ear drum is continuous with the middle ear mucosa. As soon as the middle ear mucosa is raised, the flap is pushed anteriorly till the handle of the malleus becomes visible.

Step IV: Freeing the tympano meatal flap from the handle of malleus. In this step the tympano meatal flap is freed from the handle of malleus by sharp dissection of the middle ear mucosa. Sometimes the handle of the malleus may be turned inwards hitching against the promontory. In this scenario, an attempt is made to lateralize the handle of the malleus. If it is not possible to lateralize the handle of the malleus, the small deviated tip portion of the handle can be clipped. The handle of the malleus is freshened and stripped of its mucosal covering.

Step V: Placement of graft (underlay technique). Now a properly dried temporalis fascia graft of appropriate size is introduced through the ear canal. The graft is gently pushed under the tympano meatal flap which has been elevated. The graft is insinuated under the handle of malleus. The tympano meatal flap is repositioned in such a way that it covers the free edge of the graft which has been introduced. Bits of gelfoam are placed around the edges of the raised flap. One gel foam bit is placed over the sealed perforation. This gelfoam has a specific role to play. Due to the suction effect created it pulls the graft against the edges of the perforation thus preventing medialisation of the graft material.

Type II Tympanoplasty: In this procedure the tympanic membrane is grafted to the intact incus and stapes. This procedure is very rarely used, since it is very rare for erosion of the handle of malleus to be present alone without the involvement of other ossicles. The neotympanum created is draped over the existing incus and stapes. There is a certain amount of obliteration of middle ear space.

Since the ossicular chain lever ratio is not normally maintained in these patients, they tend to have atleast 30 dB hearing loss even after a successful surgery.

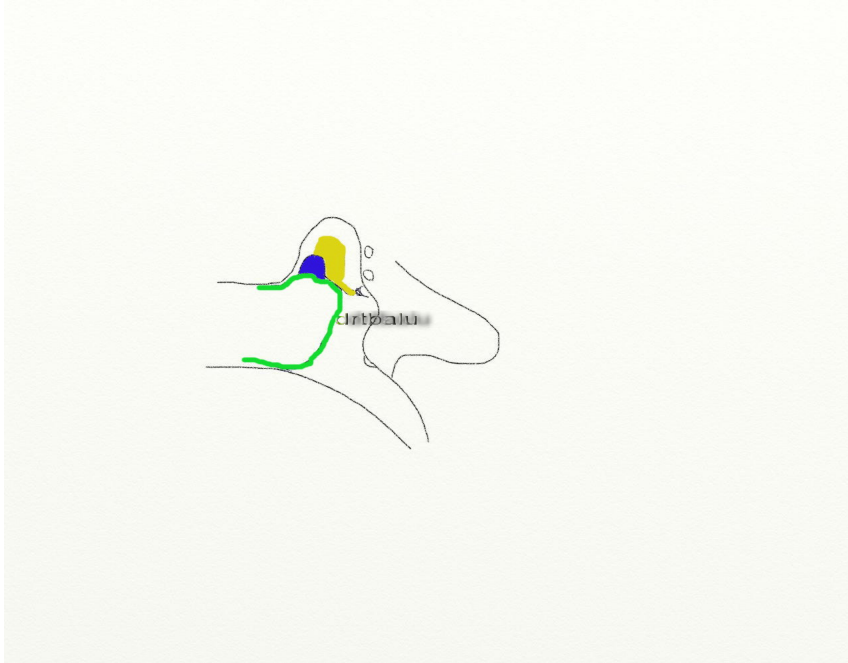


Figure showing Type II Tympanoplasty

Type III Tympanoplasty: This technique is used only when a mobile suprastructure of stapes alone is present. In this surgical procedure the tympanic membrane graft is draped over the mobile suprastructure of stapes. This is also known as Columella effect. This type of middle ear is commonly seen in birds.

The middle ear space is really non-existent. Even after successful surgery these patients still manifest with 30 – 40 dB hearing loss.

This surgical procedure is useful in patients without malleus and incus. Incus has the most precarious blood supply among the three ossicles.

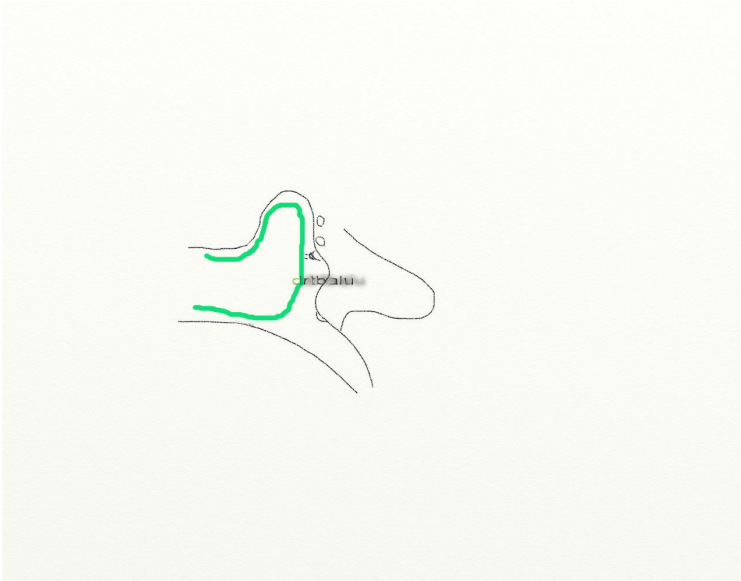


Figure showing Type III Tympanoplasty

Type IV Tympanoplasty: This surgical procedure is performed in patients only with mobile foot plate of stapes. The grafted ear drum is draped over the mobile foot plate. In these patients there is virtually no middle ear space at all. The grafted ear drum virtually drapes the promontory.

Even after successful surgery these patients still have about 40 – 50 dB hearing loss.

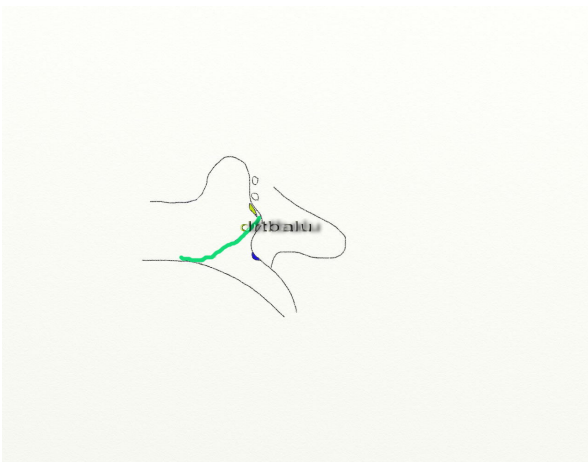


Figure showing Type IV Tympanoplasty

In this surgical procedure the round window is protected from the incoming sound waves. This helps in preserving the round window baffle effect.

Type V Tympanoplasty: In this surgical procedure a third window is created over the lateral semicircular canal. (Fenestra over lateral canal). This surgical procedure is outdated these days.

Belluci's prognostic classification: Belluci used the status of middle ear cavity in determining the prognostic features of Tympanoplasty. He grouped those under 4 heads.

Group I: Patients with a dry ear for a period of atleast 6 months fall in this category.

Group II: Patients with occasionally draining ear was included in this group.

Group III: Patients with persistent ear drainage associated with mastoiditis were included in this group

Group IV: Patients with persistent ear discharge associated with palatal malformations (cleft palate) were included in this group.

Ossicular grafts have revolutionized Tympanoplasty procedure these days. These grafts help in the preservation of middle ear space, as well as produces excellent improvement in hearing.

Implants used for ossiculoplasty should satisfy four basic requirements:

1. They should be biocompatible and should not extrude / cause severe tissue reaction
2. They should improve / maintain hearing
3. They should be technically easy to use
4. They should maintain results over time

Austin in 1971 classified the anatomical defects found in the ossicular chain due to chronic suppurative otitis media. Isolated losses of handle of malleus and stapes suprastructure were not included in this classification due to their rarity.

Type I – Normal = M+I+S

Type II – M+S – Absent incus – Good prognosis

Type III – Malleus + Foot plate of stapes – poor prognosis

The forerunner of partial and total ossicular replacement prosthesis was Dr. Austin's polyethylene malleus to foot plate strut. He designed the "sunflower Columella" designed out of Teflon. Teflon and polyethylene has the advantage of excellent air bone closure.

The following are the various categories of biomaterials used in ossiculoplasty:

1. Polyethylene tubing
2. Polytetrafluoroethylene (Teflon)
3. Gelatin foam (Gelfoam)
4. Silastic (Dimethyl silicone polymer)
5. Platinum – This material is very ductile, non magnetic and biocompatible.
6. Titanium alloy
7. Polycel and plastipore
8. Capcel – Hydroxyapatite
9. Otocel – Clear bioactive bioglass (ceramic material)

Comparison of prosthetic materials

Parameter	Cartilage	Autologous bone	Homologous bone	Plastic	Hydroxyapatite
Biocompatibility	++	+++	+++	+	+++
Storage	+++	+++	+	+++	+++
Sound conduction	+	+++	+++	++	+++
Ease of preparation	+	+	++	+++	++
Transmission of disease	-	-	Possible	-	-
Interposition graft	-	-	-	Required	-

Selection of prosthesis:

Factors to be considered while selecting an optimal prosthetic design are:

1. Status of ear drum
2. Status of residual ossicles
3. Severity of Eustachian tube dysfunction
4. Stability of prosthesis
5. Ease of placement
6. Sound conductivity

Stapes to malleus reconstruction:

When malleus is present, it can be used to help to stabilize the prosthesis and reduce the possibility of extrusion. The malleus is never directly aligned to the underlying stapes (M-S offset). A variety of implants have been designed to take advantage of the stabilizing effect of malleus.

Incus interposition: Guilford transposed the residual incus autograft on to its side so that it lies on the stapes capitulum and beneath the manubrium. Hearing results could be excellent if the middle ear anatomy is favorable. The incus remnants could be too short or long. Too long a incus prosthesis could lead to ankylosis. Revision surgery is difficult in such patients owing to the fixation of the prosthesis to the stapes and fallopian canal.

Zollner's sculpted incus: Zollner popularized the sculpturing of Autologous incus. This helps in obtaining a better fit. It also reduces the incidence of subsequent ankylosis. Wehr's refined this technique to include homograft ossicles. This technique could be time consuming. Remnant Autologous incus could harbor cholesteatoma.

Grote Hydroxyapatite assembly: Grote developed the first commercial Hydroxyapatite prosthesis. Its configuration attempted to accommodate the M-S offset. This prosthesis should be placed lateral to the malleus necessitating dissection of the ear drum away from the malleus. There is also the associated risk of iatrogenic perforation of the ear drum.

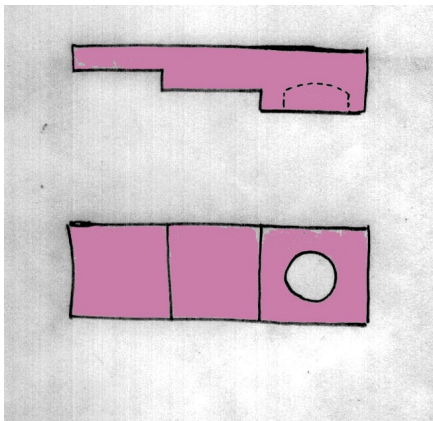


Figure showing Grote prosthesis

Wehr's Hydroxyapatite prosthesis: Wehr's advocated sculpted homograft for incus interposition. He also developed Hydroxyapatite incus prosthesis in order to reduce the preparation time inside the operation theatre during ossiculoplasty procedures. This prosthesis had an anterior extension which was created to cradle the malleus. Biocompatibility of this material was really superior.

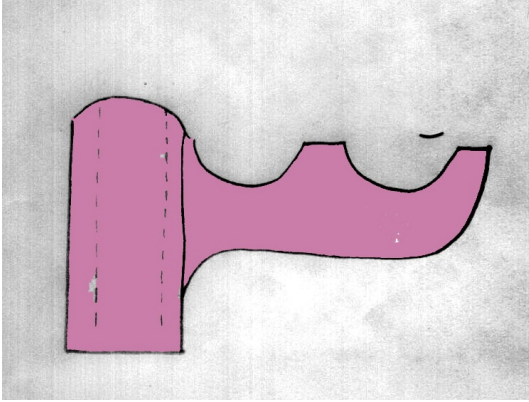


Figure showing the Wehr's prosthesis. The anterior cradle supports the malleus

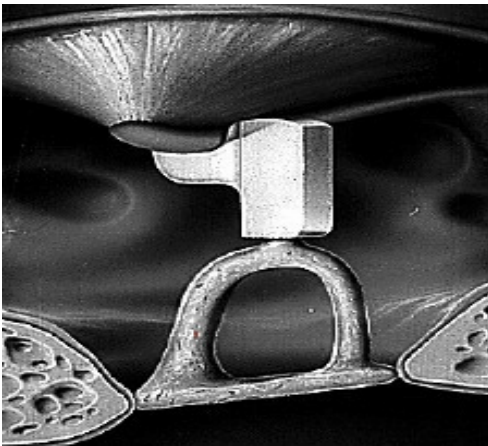


Figure showing Weher's prosthesis

There are two types of Weher's prosthesis:

1. Incus replacement prosthesis

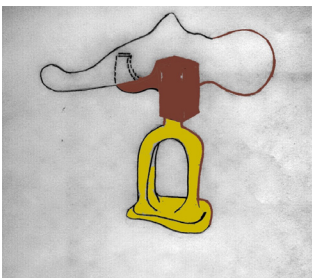


Figure showing incus replacement prosthesis

2. Incus – Stapes replacement prosthesis

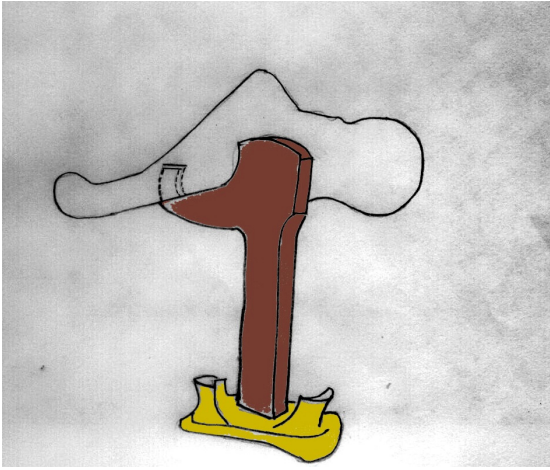


Figure showing incus – stapes replacement prosthesis

Kartush Hydroxyapatite struts: These struts were designed to function as either a TORP or PORP. Hydroxyapatite was used. This prosthesis has a self locking mechanism. It has very low displacement and extrusion rates.

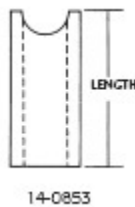


Figure showing Kartush prosthesis

Incus interposition ossiculoplasty: Incus due to its precarious blood supply commonly undergoes necrosis, especially its long process. Homograft incus was shaped and placed between the malleus and stapes head. A notch was created in the short process of the incus that fit under the malleus handle. This is done to stabilize the ossicle. If the stapes suprastructure was intact in the patient, the long process of incus was amputated. A small

cup was made in the amputated long process of incus. The head of the stapes fits into this cup. The notch prevented the prosthesis from being displaced anteriorly / posteriorly. The spring in the patient's malleus would keep the prosthesis from being displaced inferiorly. Superiorly its position is maintained by the contraction of tensor tympani tendon.

When the stapes superstructure is absent, the long process of incus could be placed over the foot plate of stapes.

Pitfalls: With AID's being common these days, incus homograft has given way to artificially designed prosthesis. Hydroxyapatite was commonly used to design these prosthetic incus replacements.

Factors that should be taken into consideration before designing the optimal prosthesis:

1. Proper tension is very important. A prosthesis that makes tension adjustment easy for the surgeon should be advantageous.
2. Prosthesis with masses less than 40mg is best for overall acoustic performance.
3. For improved high frequency performance, rigid low mass prosthesis (less than 10g) is the best choice.
4. Longer prosthesis produces excellent high frequency function at the expense of low frequencies.
5. Prosthesis that connects malleus to stapes appears to have no acoustic advantage over prosthesis that connects the ear drum to the stapes.
6. If the ear drum is conical, prosthesis with the head angulated at about 30° appears to be beneficial because the angulation increases the surface area in contact with the ear drum.

These prostheses may be used to reconstruct the ossicular chain during Tympanoplasty, in patients in whom erosion and discontinuity of ossicular chain has occurred. Long process of incus gets frequently eroded because of its precarious blood supply. In these cases the lenticular process of incus is still attached to the head of stapes. The incudo stapedial joint in these patients should be separated and the long process of incus removed. This is done because squamous debris could still be attached to the incus fragment. It is also preferable to remove the body of the incus, because it could also have squamous ingrowth. It can also have scar tissue blocking the antrum.

Surgical procedure:

The prosthesis is laid on its side on the promontory. The cup of the prosthesis is near the stapes and its notched portion close to the tip of the handle of malleus. With the help of right-angle pick held in the surgeon's left hand, the malleus is elevated, and with a

gently curved pick in the surgeon's right hand, the prosthesis is brought up under the manubrium of the malleus. As it is brought to an upright position, the cup engages the head of stapes.

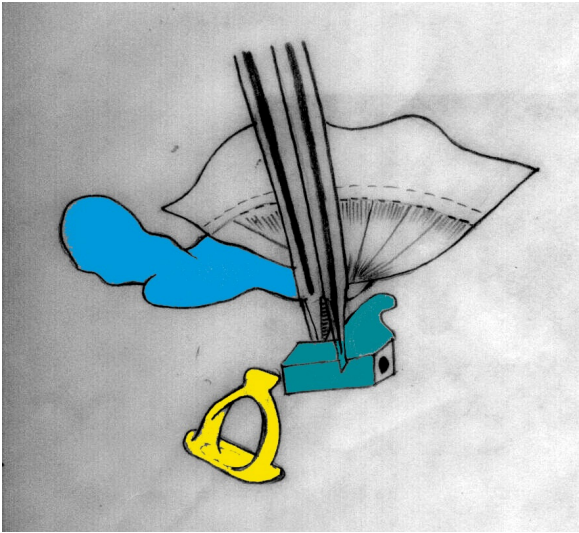


Figure showing the prosthesis laid on its side on the promontory

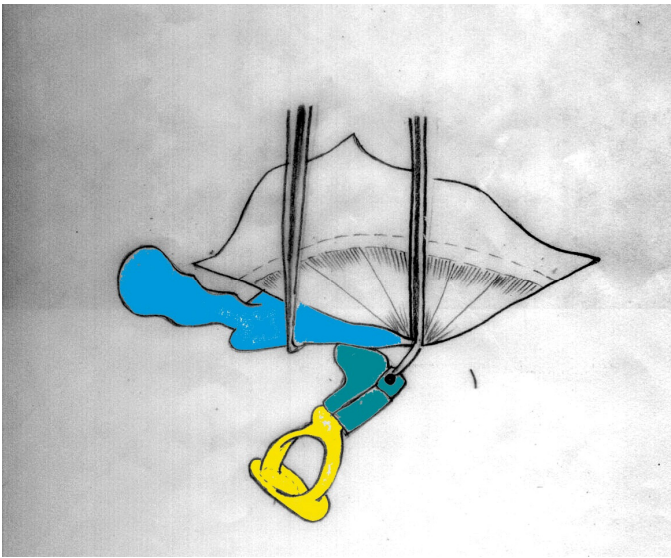


Figure showing the prosthesis being positioned

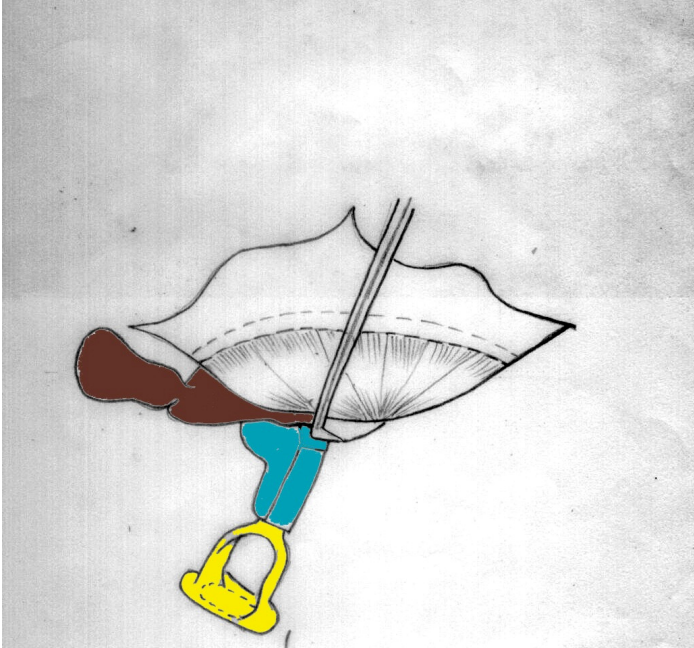


Figure showing the prosthesis in its final position

Ossicular reconstruction with prosthesis of Hydroxyapatite should not be attempted in cases of acute trauma / traumatic perforation of ear drum. It should be performed only after the drum has healed and stabilized.

Complications:

Owing to the biocompatibility of this prosthesis, the incidence of complications is rare.

1. Extrusion of the prosthesis.
2. Too short / Too long prosthesis could lead to increased extrusion rates
3. Failure to improve hearing

The success or failure of ossiculoplasty procedure could be assessed by calculating the Middle Ear Risk (MER) Index. In this index a value is assigned for each risk factor, and these values are added to determine the MER index.

MER Index

Risk factor	Risk value
Otorrhea (Bellucci criteria)	
I: Dry	0
II. Occasionally wet	1
III: Persistently wet	2
IV: Wet ear with cleft palate	3
Perforation:	
Absent	0
Present	1
Cholesteatoma	
Absent	0
Present	1
Ossicular status (Austin)	
0: M+I+S	0
A: M+S+	1
B: M+S-	2
C: M-S+	3
D: M-S-	4
E: Ossicle head fixation	2
F: Stapes fixation	3

Middle ear: granulations / effusion	
No	0
Yes	1
Previous surgery:	
None	0
Staged	1
Revision	2

According to MER:

0 – Best prognosis

2 – Mild risk

5 – Moderate risk

7 – Severe risk

12 – Worst prognosis

Ossiculoplasty using presculptured banked cartilage:

Homologous cartilage can be sculptured prior to surgery into TORP / PORP configuration. They can easily be stored by a tissue bank for use at a later date. It is configured in a self stabilizing manner with a disk shaped upper surface.

Donors should be screened serologically for Hepatitis and HIV antigens. Costal cartilage is ideal for this purpose. Graft material is harvested from the costochondral cartilages. These cartilages are fashioned into TORP type implants. The classic TORP configuration is about 8 mm long. It has a disk like head of about 4 mm diameter. The diameter of the shaft should be 2 mm in diameter.

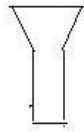


Figure showing PORP configuration to be used when malleus is absent

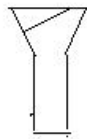


Figure showing PORP configuration to be used when malleus is present

The disk like top of the implant can be placed in contact with the posterior bony annulus for added stabilization. It is better to thin the cartilage in the area of contact with the annulus, thereby minimizing the potential for dense adhesions.

TORP configuration: Ossicular reconstruction in the absence of stapes suprastructure is technically more demanding. Cartilaginous homografts are effective if the patient has a wide oval window niche. Measurements are taken as described for PORP configuration. The length of the shaft should be trimmed and contoured as per requirements.

If there is a perforation in the tympanic membrane that corresponds with the location of the disk shaped head of the reconstruction prosthesis, the head of the prosthesis itself can be used as a graft for the perforation. The surface of the TORP readily epithelializes.

Advantages of presculptured homograft cartilage as prosthesis:

1. The incidence of graft extrusion is rare
2. Contact of the implant with adjacent bony walls of middle ear can be consistent with excellent hearing results, because the cartilage remains flexible.
3. Hearing improvement is excellent
4. Operating technique is less demanding when presculptured cartilage homograft is used.

Ossiculoplasty with composite prosthesis: PORP's and TORP's designed out of composite materials was first popularized by Sheehy and Shea. Major advantage of using synthetic graft is there is no fear of transmission of diseases like HIV and Hepatitis. Composite prosthesis has two distinct portions: a Hydroxyapatite head and a plastipore or fluoroplastic shaft. The Hydroxyapatite head is a universal design, and no modification or intraoperative reshaping is required. The plastipore shaft is manufactured in such a way that it can be precisely trimmed to within a 0.5 mm variance on the basis of intraoperative measurements.

The type of Hydroxyapatite head that should be used in the prosthesis depends upon whether malleus is present or absent. In cases where malleus is present, the head of the prosthesis used should be in the form of a delicate hook. It is designed in such a way that the hook is positioned under the handle of the malleus. The Hydroxyapatite head to be used when the malleus is absent has a flat, egg shaped design, with gently rounded edges. This design facilitates easy insertion under the ear drum without the need for cartilage interposition. This prosthesis is best used when the middle ear is healthy and free of disease.

The plastipore shaft is of two types:

1. Type I: The shaft has a hollow sleeve to accommodate the head of stapes
2. Type II: The shaft is more slender, wire reinforced. This design helps the shaft to rest directly on the foot plate of stapes / oval window.

There are 4 types of composite prosthesis designed to solve the four basic problems encountered during ossicular reconstruction. These situations include:

- Malleus present, stapes present
- Malleus present, stapes absent
- Malleus absent, stapes present
- Malleus absent, stapes absent

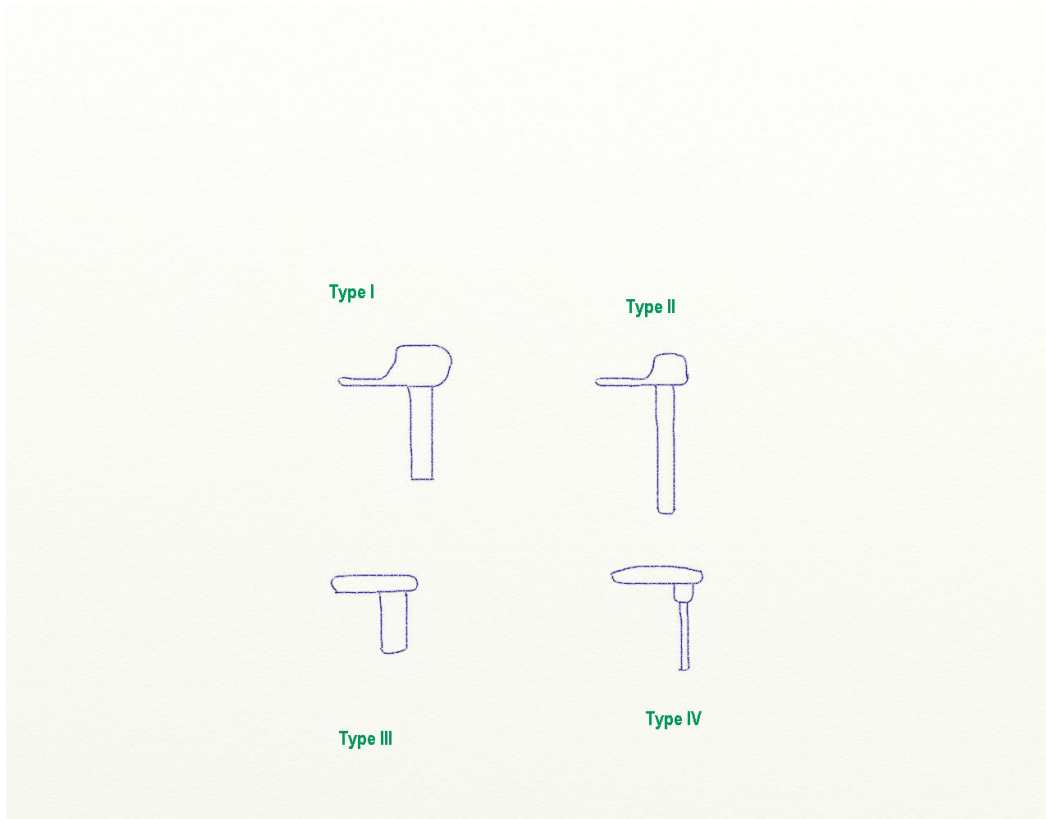


Figure showing the types of composite prosthesis

Contraindications for composite prosthesis:

1. Should not be used in patients with severe Eustachian tube function
2. Should not be used in patients with an obliterated middle ear space
3. Middle ear mucosa should be healthy and free of any disease

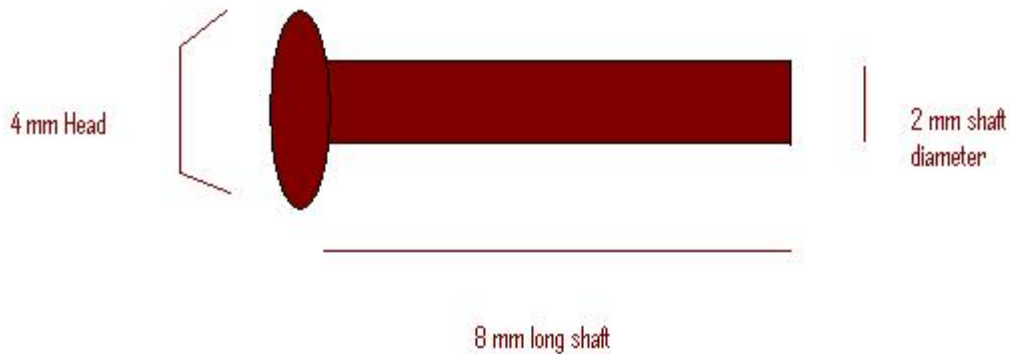


Figure showing standard TORP configuration

Cartilage harvested from rib is cut into 8 mm sections. They are then placed over sterile hard surface. Using a 4mm disposable dermal punch cylinders of cartilage are created each with 4 mm diameter and 8 mm long. From these cylindrical grafts, appropriately shaped TORP's can be prepared. Cartilage material can be placed in sterile saline and put in glass specimen sterile bottles and sealed with a plastic seal.

PORP configuration: When stapes is present and mobile, a measurement is taken from the lateral most part of the capitulum of the stapes to the ear drum. 1 mm should be added to this value, and the TORP blank cartilage is trimmed to this measurement. A depression is made in the end of the shaft of the trimmed blank to accommodate the head of the stapes. The depth of this indentation could be about 0.5 – 1 mm. The 4 mm disk of the top of the implant should be in complete contact with the ear drum. If an intact malleus handle is present, the anterior most portion of the head of the implant can be trimmed to fit the handle. If the malleus handle is absent, a more flat configuration can be used.

Spandrel: This is a type of TORP. It has a wide head which can be slid under the ear drum and a narrow shaft. The length of the shaft can be reduced by cutting it. The shaft rests over the foot plate of stapes.

Parts of spandrel: It has a perforated shoe to allow protrusion of the wire core. It has a thin flange on the prosthesis head to avoid possible damage induced by a sharp edge of the Polycel disk.

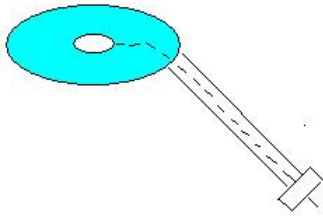


Figure showing spandrel

Before assembling the prosthesis, air is removed from the Polycel casing by connecting the prosthesis and its shoe to a syringe containing Ringer's solution and antibiotic.

This prosthesis ensures better closure of air bone gap.